



NIINA KORHONEN

Fall-Induced Injuries and Deaths Among
Older Finns Between 1970 and 2012



ACADEMIC DISSERTATION

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UNIVERSITY OF TAMPERE

NIINA KORHONEN

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ACADEMIC DISSERTATION

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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by the Roman numerals I-VI:

- I Korhonen N, Niemi S, Parkkari J, Palvanen M, Kannus P. Unintentional injury deaths among adult Finns in 1971-2008. *Injury* 2011;42(9):885-888.
- II Korhonen N, Kannus P, Niemi S, Palvanen M, Parkkari J. Fall-induced deaths among older adults: nationwide statistics in Finland between 1971 and 2009 and prediction for the future. *Injury* 2013;44(6):867-871.
- III Korhonen N, Niemi S, Palvanen M, Parkkari J, Sievänen H, Kannus P. Declining age-adjusted incidence of fall-induced injuries among elderly Finns. *Age Ageing* 2012;41(1):75-79.
- IV Korhonen N, Niemi S, Parkkari J, Sievänen H, Palvanen M, Kannus P. Continuous decline in incidence of hip fracture: nationwide statistics from Finland between 1970 and 2010. *Osteoporos Int* 2013;24(5):1599-1603.
- V Korhonen N, Niemi S, Parkkari J, Sievänen H, Kannus P. Incidence of fall-related traumatic brain injuries among older Finnish adults between 1970 and 2011. *JAMA* 2013;309(18):1891-1892.
- VI Korhonen N, Kannus P, Niemi S, Parkkari J, Sievänen H. Rapid increase in fall-induced cervical spine injuries among older Finnish adults between 1970 and 2011. *Age Ageing* 2014;43(4):567-571

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ABBREVIATIONS

ADL	Activities of daily living
BMD	Bone mineral density
BMI	Body mass index
CDC	Centers for Disease Control and Prevention
CT	Computed tomography
ED	Emergency department
FHDR	Finnish Hospital Discharge Register
GCS	Glasgow Coma Scale
ICD-10	10th Revision of the International Classification of Diseases
MRI	Magnetic resonance imaging
OCDS	Official Cause of Death Statistics
SCI	Spinal cord injury
TBI	Traumatic brain injury
WHO	World Health Organization

ABSTRACT

Falls of older adults are a major public health concern in societies with aging populations. They often result in severe injuries, long-term care, functional limitations, disability, reduced quality of life, and substantial health care costs. A fall may also lead to a death of the victim.

The objective of the thesis was to describe the epidemiology and trends in fall-induced deaths and injuries of older adults in Finland from early 1970s to 2012. The focus was especially on the latest changes in the new millennium. In addition, changes in the most severe fall-related injuries (hip fractures, head injuries and cervical spine injuries) were evaluated.

The data were obtained from two statutory registers: fall-induced deaths were drawn from the Finnish Official Cause of Death Statistics and fall-induced injuries from the Finnish Hospital Discharge Register. The annual Finnish population and population projects were obtained from Official Statistics of Finland. A fall-induced injury was defined as an injury occurring as a consequence of a fall from a standing height or less and resulting in hospital admission. The number, crude incidence (per 100 000 persons) and age-adjusted incidence of injuries and deaths were calculated for each study year. Also, the age-specific injury rates of older adults were calculated. The age-adjustment was performed separately for men and women by means of direct standardization using the mean target population between the study years as the standard population. Linear regression models were used to predict the injury rates until the year 2030.

During the study period, falls and poisonings replaced road traffic crashes as the leading causes of unintentional injury deaths among Finnish adults. At the same time, the incidence of fall-induced deaths declined among older women. Among older men the rise in this incidence also levelled off during the most recent years of observation.

The incidence of all hospital-treated fall-induced injuries of older Finns rose from the early 1970s to the late 1990s, but since then the injury rates declined. The same concerned hip fractures. In contrast, the incidence of severe head injuries and cervical spine injuries among older Finns increased during the entire study period indicating that the profile of specific fall-induced injuries among older adults has

started to change in Finland since the late 1990s. If the observed trends continue, the number of fall-induced injuries will increase during the coming decades because the older population is expanding rapidly in Finland in the near future.

The exact reasons for the observed changes in fall injuries and deaths are largely unknown. The average functional ability of older people in Finland may have improved, but, on the other hand, the frailest part of them may now fall more seriously than their predecessors. Some external risk factors for falling, such as polypharmacy, alcohol consumption and changes in living arrangements, may have also contributed to these observations.

Further studies are needed to better understand the reasons for the secular changes in the profile of fall-induced injuries and deaths of older Finns. Effective prevention of falls and subsequent injuries is needed to limit the number of these injuries and deaths in the future. This will be a major challenge for Finnish health care and the entire society.

TIIVISTELMÄ

Iäkkäiden kaatumiset ja niiden aiheuttamat vammat ovat nykyisin merkittävä kansanterveysongelma. Vammojen ja kuolemien lisäksi kaatumiset heikentävät potilaiden toimintakykyä ja elämänlaatua sekä aiheuttavat huomattavia kustannuksia yhteiskunnalle.

Tämän tutkimuksen tarkoitus oli selvittää iäkkäiden kaatumisten aiheuttamien vammojen ja kuolemien ilmaantuvuuden muutokset Suomessa 1970-luvun alusta vuoteen 2012. Erityisen mielenkiinnon kohteena olivat viimeisimmät 2000-luvulla tapahtuneet muutokset sekä kaikista vakavimmat kaatumisvammat eli lonkkamurtumat ja pää- ja kaularankavammat.

Tutkimukseen tarvittavat tiedot saatiin kahdesta suomalaisesta valtakunnallisesta rekisteristä: kaatumiskuolemien tiedot Tilastokeskuksen ylläpitämästä kuolinsyyrekisteristä ja sairaalassa hoidettujen kaatumisvammojen tiedot Terveyden ja hyvinvoinnin laitoksen (THL) ylläpitämästä terveydenhuollon hoitoilmoitusrekisteristä. Suomen väestötiedot saatiin Tilastokeskuksen vuosittaisista väestörakenteesta ja – ennuste tilastoista. Vammojen ja kuolemien lukumäärä, ilmaantuvuus (100 000 henkilöä kohti) ja ikävakioitu ilmaantuvuus laskettiin jokaiselle tutkimusvuodelle. Lisäksi laskettiin ikäryhmittäiset ilmaantuvuudet eri ikäluokille. Ikävakiointi tehtiin erikseen miehille ja naisille käyttäen suoraa ikävakiointia eli tutkimuksen vakioväestönä käytettiin koko ajanjaksolle laskettua tutkitun ikäryhmän keskivertoväestöä. Vammojen lukumäärää vuoteen 2030 asti ennustettiin lineaarisen regressiomallin avulla.

Tutkimusjakson aikana kaatumiset ja myrkytykset ohittivat liikennekuolemat yleisimpinä aikuisten tapaturmakuolemien syinä Suomessa. Toisaalta samalla ajanjaksolla kaatumiskuolemien ilmaantuvuus väheni iäkkäillä naisilla ja viimeisinä havaintovuosina tämän ilmaantuvuuden nousu taittui myös iäkkäillä miehillä.

Yleisesti iäkkäiden suomalaisten kaatumisten aiheuttamien vammojen ilmaantuvuus lisääntyi 1970-luvulta 1990-luvun loppupuolelle asti ja sen jälkeen ilmaantuvuus on jatkuvasti laskenut. Sama havainto koski myös lonkkamurtumia. Sen sijaan iäkkäiden suomalaisten vakavien päävammojen ja kaularankavammojen ilmaantuvuus lisääntyi koko tutkimusjakson ajan. Yhdessä nämä havainnot osoittivat, että iäkkäiden kaatumisten aiheuttamien vammojen profiili on muuttunut

varsin nopeasti viimeisten vuosikymmenten aikana. Kaikkiaan kaatumisten aiheuttamien vammojen lukumäärä tulee Suomessa lisääntymään vuoteen 2030 mennessä, sillä iäkkäiden määrä ja osuus väestöstä kasvavat nopeasti jo aivan lähitulevaisuudessa.

Tarkkoja syitä edellä mainituille epidemiologisille muutoksille ei tiedetä. Iäkkäiden suomalaisten toimintakyky on keskimäärin parantunut, mutta toisaalta kaikkien huonokuntoisimpien osuus on voinut lisääntyä ja he saattavat kaatuessaan saada entistä vakavampia vammoja. Joillakin ulkoisilla riskitekijöillä, kuten lääkityksien, alkoholin käytön ja ympäristötekijöiden muutoksilla, on voinut olla myös vaikutusta.

Lisätutkimuksia tarvitaan, jotta voitaisiin entistä paremmin ymmärtää iäkkäiden kaatumisvammojen ja -kuolemien profiilin muutoksiin johtaneita tekijöitä. Lisäksi tarvitaan systemaattisia toimia kaatumisten ja niistä aiheutuvien vammojen ehkäisemiseksi. Tämä tulee olemaan suuri haaste suomalaiselle yhteiskunnalle ja sen ehkäisevälle terveydenhuollolle.

1 INTRODUCTION

In the 5.5 million population of Finland, annually nearly 1.2 million accidents or assaults lead to physical injury (Haikonen and Lounamaa 2010). It has been estimated that Finnish adults make over 400 000 doctor visits per year because of injuries resulting in tens of thousands of hospital admissions (Haikonen and Lounamaa 2010). Injuries can cause up to 35% of all emergency department visits (Degutis and Greve 2006). Moreover, two to three thousand people die in accidents in Finland each year and injuries are the fourth leading cause of death in this country (Tiirikainen 2009; Official Statistics of Finland 2013a).

Injuries can be divided into two categories based on intent: unintentional or intentional (Degutis and Greve 2006). In unintentional injuries, the harmful outcome is not planned. These injuries, such as motor vehicle crashes and falls, account approximately two thirds of injury deaths (Degutis and Greve 2006). Intentional injuries may be inflicted by others (violent injuries and homicides) or they can be self-inflicted (self-harms and suicide).

It has been reported that the overall unintentional injury mortality rate declined in the 1970s and 1980s but since the early 1990s the injury mortality has started to stabilize or even increase (Jemal et al. 2005; Paulozzi et al. 2006). The majority of the increase has resulted from the rise in deaths due to poisonings and falls (Paulozzi et al. 2006; Hu and Baker 2009).

In Finland, there are about 400 000 fall-induced injuries per year and many of them require medical treatment (Haikonen and Lounamaa 2010). The majority of fall injuries occur in older adults and falls are the leading cause of injury and unintentional injury death among them (Kannus et al. 2005d; Dellinger and Stevens 2006; Honkanen et al. 2008). Thus, it is not surprising that falls and related injuries have been recognized as a major public health burden in Finland and other societies with aging populations (Tinetti and Speechley 1989; Kannus et al. 1999; Hartholt et al. 2010).

However, precise and up-to-date information on the trends of fall-induced injuries and deaths among older adults is sparse. To prevent these injuries, it is necessary to have knowledge on their frequency and details on various types of injury. The urgent need for this information is enhanced by the fact that the

number of older adults is increasing very rapidly worldwide. In Finland, for example, the proportion of people aged 65 years or over is estimated to rise from the present 18% to 26% by the year 2030 (Official Statistics of Finland 2012b). At the same time, the number of the 80-year-old or older population will more than double (Official Statistics of Finland 2012b). Clearly, we need fresh, reliable statistics on injuries of our aging population. This information is crucial for health care planning and proper management of the health care costs in the future.

The purpose of this thesis is to describe the trends in fall-induced deaths and injuries of older adults in Finland from early 1970s to present day. In particular, the objective is to focus on changes in the new millennium. The thesis also provides updated information on the incidence of very severe fall-related injuries (hip fractures and injuries to the head and cervical spine).

2 REVIEW OF THE LITERATURE

2.1 Consequences of falls among older adults

Falling is defined as an event in which a person unintentionally comes to rest on the ground or other lower level (Hoidrup et al. 2003; Tiirikainen 2009). Falls are common among older adults since approximately 30% of people aged 65 years or older fall each year. This proportion increases with age, up to 50 % by the age of 80 years (Tinetti and Williams 1997; Hoidrup et al. 2003; Gillespie 2004). In addition, many of those who fall do so repeatedly (Gillespie 2004; Kannus et al. 2005d; Hartholt et al. 2010). Among institutionalized older adults falls are about two times more frequent than among those living in the community (Rubenstein and Josephson 2002). Recurring falls are especially common in institutions (Saari et al. 2007).

Women suffer from falls and injurious falls more often than men (Kannus et al. 1999; Hoidrup et al. 2003; Shinoda-Tagawa and Clark 2003; Stevens and Sogolow 2005; Kannus et al. 2005d; Nordström et al. 2011) although it has been also reported that the percentages of older men and women who fall (with or without injuries) can be similar (Stevens et al. 2008).

Older adults have an increased susceptibility for falls and subsequent injuries because of physiologic, sensory, and cognitive changes associated with aging and a high prevalence of comorbidity, such as dementia, ischemic heart disease, stroke, osteoarthritis and osteoporosis (Rubenstein and Josephson 2002). Also, they have delayed functional recovery after an injury compared with younger adults (Ambrose et al. 2013). Therefore, even a low-energy trauma, such as a simple fall, is potentially dangerous and may cause severe injuries among older population.

2.1.1 Fall-induced injuries

Although not all falls lead to injury, approximately 30% of all falls require medical attention often resulting in emergency department (ED) visit (Stevens et al. 2008; Hartholt et al. 2011b). In Finland, over 70% of falls lead to some kind of medical

care among people 75 years of age or older (Haikonen and Lounamaa 2010). Around 5-10% of falls result in serious injuries, such as fractures, joint distortions or dislocations, soft tissue contusions and lacerations, or severe head injuries (Tinetti and Williams 1997; Kannus et al. 2005d; Nachreiner et al. 2007; Hartholt et al. 2010). These severe injuries frequently require hospital admissions among older adults. It has been estimated that 18-33% of all falls among older adults are serious enough to warrant admission to hospital (Watson et al. 2011; Hartholt et al. 2011c).

Usually, falls of home-dwelling older adults take place at home or on the yard near home (Nachreiner et al. 2007; Tiirikainen 2009), but it has been estimated that about 20% of falls with serious consequences occur on public traffic areas (Tiirikainen 2009). The majority of injurious falls among the oldest old occur indoors with no seasonal variation (Saari et al. 2007). It has been estimated that among older adults one fifth of falls occurring indoors and one tenth occurring outdoors lead to hospitalization (Sievänen et al. 2014). Most of the fall incidents have been reported happening on the stairs, or near a bed or chair (Hartholt et al. 2010). In many cases, the frail older person is found on the floor and in the absence of witnesses the mechanism of the injury remains uncertain (Honkanen et al. 2008).

In older adults, lowest rates of falls occur among community-living, generally healthy people while persons living in long-term care institutions have much higher fall rates and their falls also tend to result in more serious complications (Rubenstein 2006). Among persons living in long-term care most falls happen while walking although around one fourth of their falls occur even when standing quietly or sitting down (Robinovitch et al. 2013).

Compared with younger people, older adults are at a higher risk for injury to the head, neck, and pelvis (Sterling et al. 2001; Siracuse et al. 2012) and worse outcome after a fall (Sterling et al. 2001). The most typical severe injuries caused by falls of older people are hip fractures, wrist and upper arm fractures, and brain injuries (Saari et al. 2007; Hartholt et al. 2010; Orces 2010; Watson and Mitchell 2011). It has been reported that head and neck are most commonly affected body parts in non-fatal falls of older adults treated in EDs (Stevens and Sogolow 2005). Among people 80 years of age or older, injuries to the hip have been very common, followed by injuries to the head (Mitchell et al. 2010). The proportion of skull fractures and intracranial injuries are two times higher in men than women, whereas women are more likely to sustain hip fractures (Orces 2010).

2.1.2 Fall-induced deaths

The most serious consequence of a fall is death and most victims are older adults. The incidence of fall-related death in the population begins to increase exponentially after 50 years of age (Wendelboe and Landen 2011). Approximately 90% of fall-induced deaths have been reported occurring in people aged 65 years or older (Hartholt et al. 2012a). The mean age of the decedents has been over 80 years (Chisholm and Harruff 2010).

High age (more than 70 years) and low Glasgow Coma Scale (GCS) score (under 15) have been found to be significant predictors of mortality after a fall (Spaniolas et al. 2010). Also, male sex, and atrial fibrillation and other cardiac conditions have been identified as predictors of death (Siracuse et al. 2012). Around half of falls leading to death take place inside the home or in its immediate vicinity, while 20% occur in care institutions (Official Statistics of Finland 2013a).

Most of the fatal falls do not lead to immediate death but to a chain of morbid events that are eventually fatal (Thierauf et al. 2010). Intracranial injuries and proximal femur fractures are the most common fatal fall injuries (Official Statistics of Finland 2013a). Complications after hip fracture may account for 30-50% of these deaths (Deprey 2009; Stevens and Rudd 2014). In fatal falls, women rather than men are more likely to have hip fracture (Chisholm and Harruff 2010).

Head injuries, such as subdural hematoma, also account for many fall-induced deaths (Deprey 2009). These injuries may cover even half of all cases (Thomas et al. 2008; Thierauf et al. 2010; Stevens and Rudd 2014) and are more common among men (Thomas et al. 2008; Chisholm and Harruff 2010). Those who die because of a fall-induced head injury are in average 5 years younger than those who die because of a non-head injury (Chisholm and Harruff 2010).

In this context it is good to remember that the immediate cause of death, such as pneumonia or pulmonary embolism, can be a late complication of a fall-induced injury (Thierauf et al. 2010). This may mean underreporting of annual fall deaths (Betz et al. 2008).

2.1.3 Socio-economic consequences of falls

In addition to physical injuries, falls may reduce the quality of life among older people because easily they result in long-standing pain, functional impairment and disability (Tinetti and Speechley 1989; Kannus et al. 1999; Stel et al. 2004). Around 35% of older adults who had fallen reported a decline in functional status as a

direct consequence of the latest fall (Stel et al. 2004). Both hospital admitted and non-admitted patients reported a reduced quality of life score after a fall, even nine months after the incident (Hartholt et al. 2011c). Fall-induced hospital admissions represent the most important source of disability for older persons living in the community despite of the presence of physical frailty (Gill et al. 2004). Female gender, higher medication use, and depressive symptoms have been identified as risk factors for functional decline after falling (Stel et al. 2004).

There is close relationship between falls and long-term placement in a nursing facility (Tinetti and Williams 1997). In general, the discharge destination after an injury for older hospitalized patients has changed dramatically over the past two decades: the frequency of discharge to home has decreased steadily and discharges to short-term or long-term care facilities have increased (Shinoda-Tagawa and Clark 2003). In Finland, it has been estimated that one third of older adults are permanently institutionalized after a severe fall-induced injury (Honkanen et al. 2008).

Another negative consequence of falls is fear of falling. It has been reported that 30-70% of older persons who have fallen acknowledge fear of falling (Rubenstein and Josephson 2002; Scheffer et al. 2008; Boyd and Stevens 2009). Fear may lead to a loss of confidence in the ability to ambulate safely and restriction in mobility. Up to 40% of older adults who fall will restrict their activities of daily living (ADL) (Ambrose et al. 2013). This then may result in further functional decline, depression, feelings of helplessness, and social isolation (Rubenstein and Josephson 2002; Scheffer et al. 2008; Boyd and Stevens 2009).

Falls have a large impact on health care costs (Dellinger and Stevens 2006; Heinrich et al. 2010; Watson et al. 2011). Fall-related costs are between 0.85-1.5% of all health care expenditures in the USA, Australia and the United Kingdom (Heinrich et al. 2010). Comparisons of the costs of falls with costs of other diseases are limited but it seems that costs of falls are higher than the costs of epilepsy, comparable to those of depression and dementia, and lower than the costs of stroke (Heinrich et al. 2010).

With regard to the costs, most expensive fall injuries are hip fractures, pelvic fractures, and brain injuries (Hartholt et al. 2012b). The cost per fall increases with the age of the patient (Hartholt et al. 2012b) and is higher in females (Stevens et al. 2006; Hartholt et al. 2012b). The majority of total costs have been associated with hospital treatment and care (inpatient, emergency department and outpatient) although costs of rehabilitation and after-care can also be extensive (Watson et al. 2011).

In Finland, there is no fresh, precise information on the costs of fall-induced injuries besides fractures. Hip fractures are the most expensive fractures following a fall: the total costs of a hip fracture (in 2007 level of costs) during the first year after the injury are around 17 000 euro per patient. If a patient formerly living at home will be institutionalized after the hip fracture (which occurs in about 10% of cases) the costs during the first year after the injury are around 42 000 euro per patient (Honkanen et al. 2008).

2.2 Risk factors for falls

Fall risk factors have been defined as person-specific (or intrinsic) and environmental (or extrinsic) (Ambrose et al. 2013). Intrinsic risk factors include factors such as age over 80, female gender, gait and balance disorders (and specific conditions leading to them such as Parkinson's disease), muscle weakness, visual impairment, cognitive impairment, dizziness and vertigo, orthostatic hypotension, urinary incontinence, low body mass index (BMI), depression, and previous fall. Typical extrinsic risk factors include polypharmacy, use of psychotropic medications and environmental hazards (for example, uneven surfaces and other tripping hazards, slippery floors, poor fitting footwear and poor lighting) (Rubenstein and Josephson 2002; The American Geriatrics Society 2010; Ambrose et al. 2013). Concerning medications, especially the use of sedatives and hypnotics, antidepressants and benzodiazepines has been associated with falls (Woolcott et al. 2009). The use of alcohol also increases the risk of a fall (Stenbacka et al. 2002; Immonen et al. 2011). In addition, the risk factors often interact so that the risk of fall increases further as the number of risk factors rises (The American Geriatrics Society 2010; Ambrose et al. 2013).

When addressing fall-induced fractures, it is important to take into consideration that many risk factors for falls are also related to reduced bone strength. Individual risk factors for low bone strength include high age, female gender, low BMI, muscle weakness, physical inactivity, smoking, vitamin D deficiency, low calcium intake, high alcohol intake, family history of fragility fracture, early menopause, late menarche, amenorrhea, rheumatoid arthritis, diabetes mellitus, depression, some gastrointestinal and endocrine diseases, and some medications (for example oral corticosteroids) (Karinkanta et al. 2010). The severity of the injury and the occurrence of fracture depend on the mechanical force of the fall impact and the degree of bone fragility (Kannus et al. 2005e; Chen

et al. 2008). Thus, low bone mineral density (BMD) (or osteoporosis) and falling both contribute to risk of fractures (Kannus et al. 2005e). However, the fall event is a stronger determinant of a fracture than bone fragility since the majority of fractures occur to people with normal or slightly lowered BMD (Stone et al. 2003; Kannus et al. 2005e; Järvinen et al. 2008).

In addition to the complex interactions between risk factors, many factors are both risk factors and consequences of falls (Figure 1). These factors can sum up creating a vicious circle. For example, depression is a risk factor for falls and fall-induced injuries, and, fear of falling after a fall can cause depression. Furthermore, antidepressant medications can increase the risk of falls (Iaboni and Flint 2013).

In summary, the highest risk for falls and fall-induced injuries is among the oldest old and people with multiple risk factors.

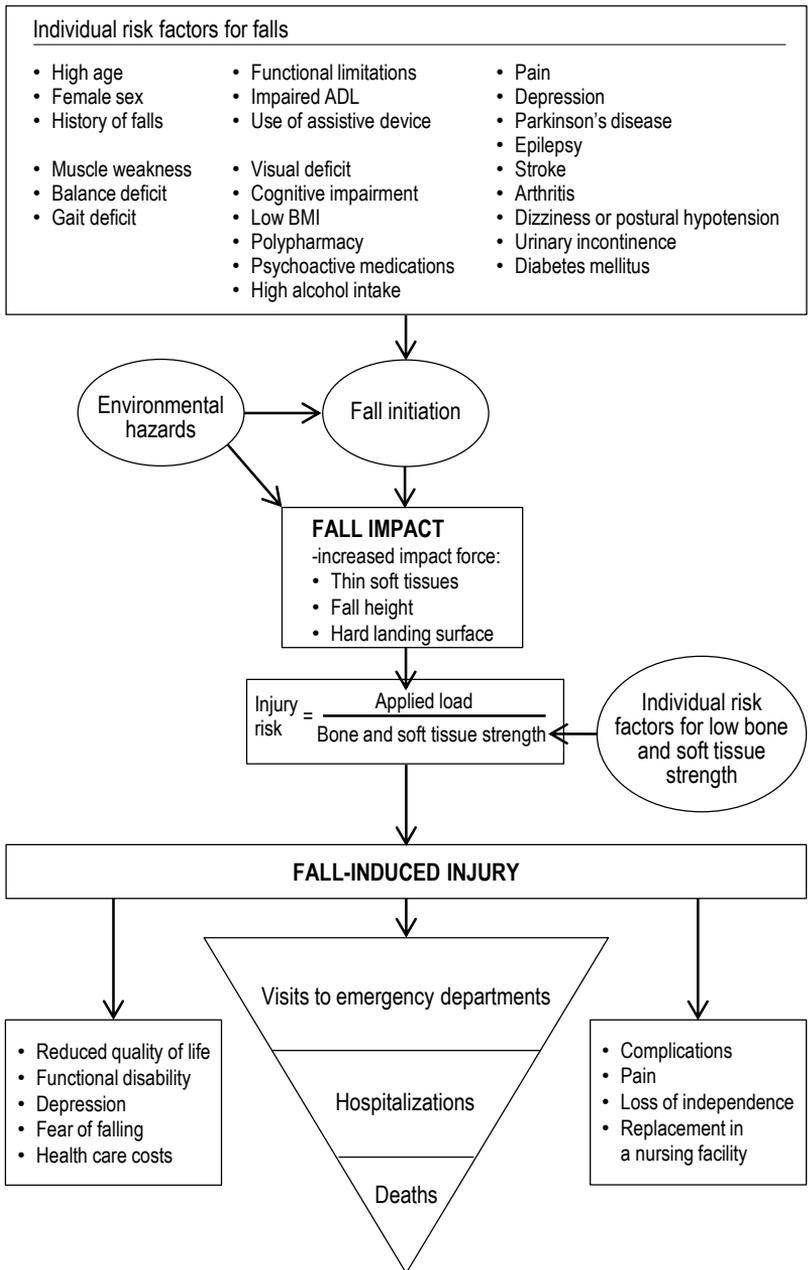


Figure 1. Risk factors and consequences of fall-induced injuries. Adapted and modified from Karinkanta et al. (2010).

2.3 Secular trends in fall-induced injuries and deaths

2.3.1 Fall-induced deaths

Worldwide, an estimated 280 000 people died because of a fall in 2000 (Peden et al. 2002; Mitchell et al. 2010). Thereafter, the estimation has increased greatly: according to the World Health Organization (WHO) each year 425 000 individuals die from falls globally (World Health Organization 2012).

The number of fall-induced deaths has increased among older adults in recent decades, for example in Texas, USA (Orces 2008) and Finland (Kannus et al. 2005c) but the secular trends in the age-adjusted mortality rates have been inconsistent. A decreasing rate was reported in the USA from 1979 to 1992, while the rate increased 40% from 1992 to 2002 (Paulozzi et al. 2006). Another report from the USA summarized that the age-adjusted incidence of fall-related mortality of people older than 65 years increased 22% among women and 58% in men between 1981 and 1998 (Orces 2008).

In the Netherlands, fall-related mortality decreased between 1969 and 2008, but over the last decade stable mortality rates were seen in women and rising rates in men (Hartholt et al. 2012a). In 2008, the age-adjusted mortality rates were 69.8 per 100 000 in women and 62.8 per 100 000 in men aged 65 years or older (Hartholt et al. 2012a). In Finland, men's fall-induced deaths have increased with a rate that cannot be explained merely by demographic changes although among women the age-adjusted incidence has declined since the 1970s (Kannus et al. 2005b). Furthermore, an Australian report showed increase in fall mortality among older adults between 1997 and 2002 (Dowling and Finch 2009).

Hu and Baker reported that the overall fall mortality increased 36% in the USA between 1999 and 2005 (Hu and Baker 2009) and 42% between 2000 and 2006 among persons aged 65 years and over (Hu and Baker 2010). Also, in 1999-2005 (Wendelboe and Landen 2011) and 2000-2009 (Rockett et al. 2012) the overall US fall mortality rate increased. Similarly, during 1993-2003 the rate of fatal falls among US persons aged 65 or over increased, the age-adjusted incidence being 46.2 (per 100 000 persons) among men and 31.1 among women in 2003 (Centers for Disease Control and Prevention (CDC) 2006).

More recent studies have also reported increasing fall mortality rates. One study concluded that in the USA unintentional fall mortality increased 22% among people aged 65 years or over during 2003-2007 and the age-adjusted incidence was

34.4 per 100 000 for women and 50.1 for men in 2007 (Alamgir et al. 2012). Another study reported that the rise has continued till 2010 (Stevens and Rudd 2014).

The age-specific rates of fall-induced deaths increase with age (Alamgir et al. 2012; Hartholt et al. 2012a) and highest rate has been observed in men aged 85 years or older (Orces 2008). In fact, many studies confirm that fall mortality is greater in men than women (Centers for Disease Control and Prevention (CDC) 2006; Orces 2008; Dowling and Finch 2009; Wendelboe and Landen 2011; Rockett et al. 2012; Alamgir et al. 2012). In addition, the only study reporting that fall-mortality rate is higher in women than men concluded that in recent years, rates for men were catching up those of women (Hartholt et al. 2012a).

2.3.2 Fall-induced injuries

Epidemiologic studies of fall-induced injuries usually take into account only serious injuries, that is, injuries that lead to hospitalization. Of all serious injuries leading to hospitalization, falls have been reported to be the mechanism of injury in almost 40% of the cases (Shinoda-Tagawa and Clark 2003). Older individuals have higher rates of fall-induced hospitalization than their younger counterparts (Mitchell et al. 2010) and the rate of fall-related injuries requiring hospital treatment increases exponentially after the age of 70 years (Hoidrup et al. 2003).

Both the number and incidence of fall-related hospital admissions among persons 65 years or older have increased in the Netherlands and USA since the 1980s (Hartholt et al. 2010; Orces 2010). In the USA, the age-adjusted hospitalization incidence among people aged 65 years old or older increased by almost 6% per year from 1988 to 2005 (Orces 2010). A more recent report showed that the number of fall-induced hospitalization among older adults has increased 50% and the age-adjusted incidence 31% in the United States in 2001-2008 (Hartholt et al. 2011b). Among the oldest old, persons aged 85 years or older, the incidence of fall-related hospitalizations was 4538 per 100 000 women and 3063 per 100 000 men in 2008 (Hartholt et al. 2011b). Another study also concluded that the age-adjusted incidence of fall-related fractures among older adults treated in US hospital EDs increased 11% between 2001 and 2008 (Orces 2013).

In the Netherlands, the annual growth of fall-related hospital admissions was 1.3% for men and 0.7% for women in 1981-2008 (Hartholt et al. 2010). For all age-specific groups of older adults the incidence was higher in women than men and a

5-10 year age shift was noticed. For example, in 2008 the incidence for men aged 85-90 years was 280.4 per 10 000 compared with 277.0 in women aged 80-85 years (Hartholt et al. 2010).

The number and age-standardized rate of fall-related injuries has also increased in New South Wales, Australia between 1998 and 2009 by 1.7% each year and was driven by the significant increase in the rate of hospitalized non-fracture injuries (Watson and Mitchell 2011). Rates for severe head injuries and rib and pelvis fractures increased, while hip and forearm fractures declined (Watson and Mitchell 2011). Among people aged 65 years or over, the age-adjusted incidence of fall-related injury hospitalizations was 2418 per 100 000 women and 1493 per 100 000 men in 2009 (Watson and Mitchell 2011).

Also in Victoria, Australia, the number of fall-related hospitalizations among people aged 65 years or over increased during 1998-2009 and an estimated yearly average increase was 4.4% (Cassell and Clapperton 2013). The age-standardized incidence increased significantly to 1951 per 100 000 in 2009 (Cassell and Clapperton 2013). The increase was driven by increases in superficial injuries, intracranial injuries, injuries to the muscles and tendons, and upper extremity fractures (Cassell and Clapperton 2013). Furthermore, a Swedish report suggested that a potential transition in fall-induced fractures has occurred with more serious fractures decreasing and less serious fractures increasing: in 1998-2010 the incidence rate of hip fractures decreased while that of other fractures increased (Nilson et al. 2013a). In Finland, both the number and age-adjusted incidence of fall-induced injuries increased between 1970 and 2002 (Kannus et al. 2005a).

The mean age of the fall injury patients has increased (Hartholt et al. 2010; Orces 2010) and the incidence rates increase with age (Hartholt et al. 2011b). The rate of fall-induced injury hospitalization is the highest for individuals aged 80 years of age or older (Mitchell et al. 2010). Most of the patients in older population are females (Stevens and Sogolow 2005; Centers for Disease Control and Prevention (CDC) 2006; Hartholt et al. 2010; Orces 2010; Mitchell et al. 2010; Hartholt et al. 2011b) and women's fall-related injury rates are 40–60% higher than those of men of comparable age (Stevens and Sogolow 2005). In particular, in women aged 80 years or older the rate of hospitalization is 1.5-times higher than that in men (Mitchell et al. 2010).

Taken together, although the incidence of fall-induced injuries has been reported to be higher among women than men, rates for fall-induced deaths are higher among men.

2.3.3 Hip fractures

A hip fracture is defined as any fracture of the proximal femur between the articular cartilage of the hip joint and 5 cm below the distal point of the lesser trochanter (Abrahamsen et al. 2009). Hip fractures can be divided into three main categories based on the location of the fracture: fractures of the neck of the femur, trochanteric fractures and subtrochanteric fractures (Hirvensalo et al. 2010). Most cases of hip fracture occur in older adults who are exposed to low-energy trauma (generally fall) with underlying and often asymptomatic bone fragility (Kannegaard et al. 2010).

Hip fractures are among the most severe fall-induced injuries. They always require treatment in a hospital and are almost invariably treated surgically (Hirvensalo et al. 2010). Therefore hip fractures are well represented in the hospitalization data of fall-induced injuries. Around 17% of women and 6% of men 50 years of age or older are predicted to sustain a hip fracture in their lifetime (Brown et al. 2012).

Hip fracture can cause devastating consequences for an elderly person. About 20% of patients are non-ambulatory even before fracture, but of those who were able to walk, half cannot do so independently afterwards (Cummings and Melton 2002). Hip fracture is often the decisive event that begins the downhill ending in death. One-year mortality after hip fracture is high: rates range from 10% to over 30% (Marks et al. 2003; Hindmarsh et al. 2009; Abrahamsen et al. 2009). Men have at least twice the risk of death following hip fracture compared with women (Piirtola et al. 2008; Hindmarsh et al. 2009; Abrahamsen et al. 2009).

Reports of secular trends in hip fracture rates are available worldwide. The incidence of hip fracture increased since the 1970s but leveled off in the 1990s in Oslo, Norway (Stoen et al. 2012). In Östergötland, Sweden the age-adjusted incidence of hip fracture increased among men but decreased among women in 1982-1996 (Löfman et al. 2002). A recent, national report from Sweden showed that in 1987-1996 the hip fracture incidence rates increased for all age- and sex-specific groups of older adults but on the contrary, decreased in 1997-2009 (Nilson et al. 2013b). In the new millennium, the incidence has declined in women in Oslo but a similar decrease was not evident in men (Stoen et al. 2012). The age-adjusted incidence of hip fracture among people aged older than 50 years was 82.0 per 10 000 women and 39.1 per 10 000 men in 2007 (Stoen et al. 2012). In Denmark, the hip fracture incidence declined from the late 1990s in both genders (Abrahamsen and Vestergaard 2010). A recent report indicated that the reduction

in fractures has continued at least until 2009 (Jorgensen et al. 2014). Like in other Scandinavian countries, in Finland the rise in the incidence of hip fracture until the late 1990s has been followed by declining fracture rates (Kannus et al. 2006).

In the Netherlands, the number of hip fractures doubled since the 1980s, but since the mid-1990s the age-adjusted incidence has decreased (Hartholt et al. 2011a). The age-adjusted incidence (per 10 000 persons) was 79.9 in women and 37.8 in men in 2008 among people 65 years of age or older (Hartholt et al. 2011a). In France, the incidence of hip fracture decreased in 2002-2008 among people 75 years old or older (Maravic et al. 2011). Moreover, the age-standardized incidence of hip fracture decreased while the incidence of other osteoporotic fractures increased in Switzerland in 2000-2007 (Lippuner et al. 2011).

Also in Australia, the age-standardized incidence of fall-related hip fractures decreased in the new millennium and was 467 per 100 000 person among people aged 65 years or older in 2009 (Cassell and Clapperton 2013). In Canada, the age-standardized hip fracture rates declined between 1985 and 2005, and since 1996 the decline even accelerated (Leslie et al. 2009). Nevertheless, the absolute number of hip fractures still increased (Leslie et al. 2009).

In the USA, the age-adjusted incidence of hip fracture increased from the 1980s to the 1990s (Brauer et al. 2009), but steadily declined thereafter till 2005-2006 (Brauer et al. 2009; Stevens and Anne Rudd 2010; Brown et al. 2012). The age-adjusted incidence of hip fracture among people 65 years or older was 793.5 per 100 000 persons in women and 369.0 in men in 2005 (Brauer et al. 2009). The declining rate of hip fractures was reported in all age groups (even among 85 years old or older) in 1997-2006 (Adams et al. 2013). Even when the fracture incidence declined, the fracture mortality was essentially unchanged (Brauer et al. 2009).

In contrast to the above noted many reports of declining hip fracture rates, the hip fracture incidence increased in Germany in 1995-2004 (Icks et al. 2008). However, an updated report states that the incidence has started to decline in Germany in recent years, at least among older women (Icks et al. 2013). Still, some Asian and South American studies have pointed towards increasing hip fracture incidences (Cooper et al. 2011; Ballane et al. 2014).

Currently, the mean age of hip fracture patient is over 80 years (Stoen et al. 2012; Brown et al. 2012) and the mean age is higher among women than men (Stoen et al. 2012). Women have the majority (60-77%) of the fractures (Leslie et al. 2009; Brauer et al. 2009; Hartholt et al. 2011a; Stoen et al. 2012; Jorgensen et al. 2014). The observed decline in incidence of hip fracture has been larger in women

than men among people aged 75 years or older (Kannus et al. 2006; Maravic et al. 2011).

2.3.4 Head injuries

Head injuries, including traumatic brain injuries (TBI), are described and defined in various ways. For example, the Centers for Disease Control and Prevention (CDC) in the USA has since 1995 defined TBI “as an injury to the head arising from blunt or penetrating trauma or from acceleration/deceleration forces associated with one or more of the following: decreased level of consciousness, amnesia, objective neurologic or neuropsychological abnormality(ies), skull fracture(s), diagnosed intracranial lesion(s), or head injury listed as a cause of death in the death certificate” (Coronado et al. 2012). In the Finnish guidelines, TBI is defined as a trauma to the head manifested by at least one of the following: any period of loss of consciousness, any loss of memory for events immediately before or after the accident, any alteration in mental state at the time of the accident (for example feeling dazed, disoriented or confused), focal neurological deficits that may or may not be transient, or abnormal intracranial imaging finding due to trauma (Current Care Guideline 2008). Compared to TBI, head injury is a more nonspecific term that includes external and internal injuries that may or may not involve TBIs (Kool et al. 2013).

Among different types of fall-induced injuries treated in EDs, TBIs result in the highest risks of death while hip fractures led to the greatest limitations in ADL immediately after the injury (Yu et al. 2013). The outcome of severe head injuries can range from full independent living to dependence on health care services or death (Hartholt et al. 2011d). It has been reported that among older adults 13% of hospitalizations due to TBI resulted in death (Harvey and Close 2012). One report even suggested that patients over 70 years of age sustaining severe head injury had 80 % mortality and no one made good recovery at six months (Mak et al. 2012). It seems that the overall mortality after TBI among older adults is around 40% with mortality increasing with injury severity (McIntyre et al. 2013). GCS score, type of head injury, and age have been identified as predictors of mortality in the older population (Utomo et al. 2009).

Incomplete recovery from TBI can result in lifelong cognitive, emotional, sensory, motor, and other impairments (Rutland-Brown et al. 2006). In older adults relatively high proportions of mortality and disability have been reported despite

the high number of cases with an initially mild TBI (defined as GCS score of 13 to 15 at the time of hospital admission) (Coronado et al. 2005). This suggests that older adults suffer worse outcomes even when they experience relatively minor head injuries (Coronado et al. 2005).

Falls are the leading cause of TBI (Kleiven et al. 2003; Rutland-Brown et al. 2006; Harvey and Close 2012). The highest rates of TBI hospitalization and deaths have been reported among persons aged 65 years or older (Rutland-Brown et al. 2006; Kool et al. 2013). TBI accounts for around 8% of all fall-related hospitalizations in older population (Thomas et al. 2008).

In hospitalizations due to TBI, subdural hemorrhage has been reported the most common type of injury (43% of cases), followed by concussive injury and subarachnoid hemorrhage (Harvey and Close 2012). Also, among fatal head injuries caused by falls, most (86%) are subdural hematomas, followed by subarachnoid hemorrhages, cerebral contusions, skull fractures and intracerebral hemorrhages (Chisholm and Harruff 2010). Among elderly patients with fatal fall, many exhibited no sign of head injury immediately after their fall (Chisholm and Harruff 2010).

Prior studies have mainly reported an increasing trend in the incidence of TBI among older adults. In Sweden, the incidence rate of head injury clearly rose among men and women aged 65 years or over in 1987-2000 (Kleiven et al. 2003). In the Netherlands, the annual number of fall-related traumatic head injury hospitalizations increased 223% among older adults between 1986 and 2008 (Hartholt et al. 2011d). The incidence rate increased annually by 1.2% in 1986-2000 but since 2001 the increase accelerated up to 11.6% per year (Hartholt et al. 2011d). The age-adjusted incidence of head injury among people aged 65 years or over was 113.3 per 100 000 men and 123.6 per 100 000 women (Hartholt et al. 2011d). Also in Finland, both the number and age-adjusted incidence of fall-induced severe head injuries increased steeply from 1970 to 2004 (Kannus et al. 2007a).

Furthermore, the incidence of fall-related TBI increased in Australia by 8.4% per year between 1998 and 2011 (Harvey and Close 2012). In the same way, a linear increase in fall-induced TBI hospitalizations was observed in New Zealand during 2000-2009 (Kool et al. 2013). In Pennsylvania, USA, incidence of TBI among older adults nearly doubled in 1992-2009 (Ramanathan et al. 2012). Also in Oklahoma, USA, the rate of fall-induced TBIs increased almost 130% in 1992-2003 while the case-fatality decreased (Fletcher et al. 2007). In 2001-2003, the rate of fall-induced TBI among people aged 65 years or over was 182.7 per 100 000

persons while among people 85 years or older the rate of TBI (including all causes) was 566.2 per 100 000 persons (Fletcher et al. 2007).

Among older adults, most TBIs occur in the oldest old (people aged 85 years or older) (Coronado et al. 2005) who have almost 6 times higher rates of intracranial injury than those aged 60-64 years (Jamieson and Roberts-Thomson 2007). It has also been shown that in recent years (in 2007-2010) trauma center admissions due to TBI among people 75 years or older have increased 20-25% relative to the general population (Dams-O'Connor et al. 2013). The age-specific incidence of TBIs increased especially in persons aged 85 years or older (Kleiven et al. 2003; Hartholt et al. 2011d). In addition, the increase has been greatest in the age group with the poorest outcomes following TBI (people aged 83 years or older) (Ramanathan et al. 2012).

Hospitalizations for fall-induced TBI have been reported to be similar among older men and women (Thomas et al. 2008; Hartholt et al. 2011d), although males have also been reported to have slightly higher hospitalization rates (Kleiven et al. 2003; Coronado et al. 2005; Jamieson and Roberts-Thomson 2007; Harvey and Close 2012; Ramanathan et al. 2012; Kool et al. 2013).

Regarding the most serious consequence of TBI, fall-related TBI deaths increased in the USA between 1997 and 2007 (Coronado et al. 2011). The rate of TBI deaths among men has been reported to be higher than that among women (Coronado et al. 2011; Kool et al. 2013). Highest rates were among men aged 85 years or older (Coronado et al. 2011).

2.3.5 Cervical spine injuries

Cervical spine injuries consist of spinal cord injuries (SCI) or fractures to the cervical spine - alone or in combination. Older patients can sustain cervical spine injuries after a seemingly minor trauma (Wang et al. 2013) because of diminished flexion-extension mobility of the cervical spine and spinal stenosis (Hagen et al. 2005). Thus it is not surprising that the majority of these injuries among older persons are caused by falls (Brolin 2003; Golob et al. 2008; Malik et al. 2008; Couris et al. 2010; Selvarajah et al. 2014; Mitchell et al. 2014).

Out of all traumatic SCI among older adults, the majority affects the cervical spine (67% of cases) (Selvarajah et al. 2014). Cervical spine fracture is a relatively rare fall-induced injury among older adults (Siracuse et al. 2012), but it can be a

severe and disabling condition for the victim and related mortality is often high (Golob et al. 2008; Harris et al. 2010).

Cervical spine injuries and TBI can overlap to some degree. According to a recent report from the USA, older adults with traumatic SCI had concurrent TBI in 10% of cases (Selvarajah et al. 2014). Intracranial pathology has also been reported as a co-injury in 6% of fall-induced cervical spine fractures among older adults and advanced age and male sex could be identified to predict this co-injury pattern (Wang et al. 2013). In fatal head injuries, associated cervical vertebrae fractures occurred in 8% of cases (Chisholm and Harruff 2010).

The risk of death after cervical spine fracture is high: 28% mortality has been reported at one year after the incident (Harris et al. 2010). Also mortality of 24-30% has been reported (Damadi et al. 2008; Golob et al. 2008; Malik et al. 2008) with respiratory failure as the most common immediate cause of death (Damadi et al. 2008). Out of fatal non-head injuries caused by falls, 11% were cervical spine fractures (Chisholm and Harruff 2010). High mortality has been associated with neurological involvement (Damadi et al. 2008; Harris et al. 2010), but also isolated cervical spine fracture without SCI has led to high mortality (Golob et al. 2008). Furthermore, increased age and comorbid conditions have been associated to increased risk of mortality (Harris et al. 2010). In addition to the high mortality, many of these injuries lead to a placement in a long-term care facility (Golob et al. 2008). Even so, there have been reports of patients regaining good function and returning home after discharge (Hagen et al. 2005; Damadi et al. 2008).

Among older people, the majority of cervical spine fracture seems to occur at the upper cervical spine; that is, at the C1-C2 level (Lomoschitz et al. 2002; Brodin 2003; Golob et al. 2008; Malik et al. 2008; Wang et al. 2013). This can be due to the degenerative changes in the spine, which leads to stiffening of the vertebral column and the C1-C2 segment becoming the most mobile and vulnerable portion (Lomoschitz et al. 2002; Malik et al. 2008).

Among older adults with cervical spine fracture, 22% had SCI (that is, neurologic deficits or radiologic evidence of spinal cord involvement) (Golob et al. 2008) and most of these patients have been reported to have incomplete SCI (Hagen et al. 2005). It appears that neurological injury associated with cervical trauma is less common in elderly patients due to the more minor nature of the trauma compared with younger people. When a neurological injury does occur in older adults, it is more commonly incomplete (Malik et al. 2008).

Treatment of cervical spine fractures requires stabilization and immobility which can be achieved with rigid collars, halo-vest placement, or surgery (Weller et

al. 1997; Golob et al. 2008; Damadi et al. 2008). A recent review suggested that 57% of upper cervical spine injuries in elderly patients are treated surgically (Jubert et al. 2013). All of these treatments can be very hard for the patient and prone to complications (Golob et al. 2008; Damadi et al. 2008; Malik et al. 2008; Jubert et al. 2013). A small pilot study showed that lower respiratory tract infections, delirium and new falls occur commonly in older people immobilized with external orthoses following cervical spine fracture (Moran et al. 2013).

Previous studies have reported increasing numbers of cervical spine injuries and traumatic SCI among older adults. In Sweden, the incidence of cervical spine fracture doubled over the period 1987-1999 for persons aged 65 years or over while in younger age groups the incidence was stable or decreased (Brolin 2003). Traumatic SCI due to falls has also been increasing steadily in the USA (Devivo 2012). In Iceland, the incidence trend of fall-induced traumatic SCI fluctuated in 1975-2009, but increased significantly in 2005-2009 (Knutzdottir et al. 2012). Falls were the second leading cause of traumatic SCI in Spain and these injuries showed an increase over the last two decades (Van Den Berg et al. 2011). An Australian report also showed increase in hospitalization rate following C1 or C2 fractures in 1998-2010 with the highest rate for individuals aged 85 years or over (Mitchell et al. 2014).

In Finland, a study using the register of the Käpylä Rehabilitation Centre revealed that the incidence of traumatic SCI among people 55 years old or older increased in 1976-2005 and that during that time falling became the leading cause of injury followed by traffic accidents (Ahoniemi et al. 2008). A nationwide Finnish epidemiologic study also showed that that overall number as well as age-standardized incidence of fall-induced severe cervical spine injuries of older adults clearly increased from 1970 through 2004 (Kannus et al. 2007b).

The incidence of cervical spine injuries is different between sexes since men have higher incidence of cervical spine injuries than women (Brolin 2003; Malik et al. 2008; Fredo et al. 2012). The incidence of cervical spine fractures increases significantly with age (Fredo et al. 2012). Further, the incidence of traumatic SCI for persons 80 years or older has been three to four times higher than the incidence in age groups less than 60 years (Couris et al. 2010). It has also been reported that people older than 70 years of age are at the greatest risk for sustaining a fall-related SCI (Van Den Berg et al. 2011).

2.4 Prevention of falls

Preventive interventions can be primary, secondary or tertiary, and, strategies can be individual, population-based, or environmental (Degutis and Greve 2006). Especially in recent years many prevention studies aiming to reduce falls of older individuals have been conducted. Single intervention means that the intervention focuses only on one certain aspect of falls prevention, for example, exercise, medication adjustment, or vision improvement. Multiple or multi-component interventions combine more than one preventive measures together and offer them to all participants. Multifactorial interventions are based on individually-tailored preventive measures selected after an individual fall risk assessment (The American Geriatrics Society 2010).

Among community-dwelling older people, exercise programs (usually containing balance and strength training), have been reported to significantly reduce the rate of falls and risk of falling (Karinkanta et al. 2010; Gillespie et al. 2012). In hospital settings, exercise appears effective in subacute hospitals but in care facilities effectiveness has remained uncertain (Cameron et al. 2012). Multifactorial interventions (including individual risk assessment) can reduce rate of falls in the community and hospitals but not the risk of falling (Gillespie et al. 2012; Cameron et al. 2012). Recommendations have been made that assessment and treatment of postural hypotension and exercise should be included in every multifactorial intervention (The American Geriatrics Society 2010).

Vitamin D supplements (usually with calcium) may reduce risk of falling in people with lower vitamin D levels (Gillespie et al. 2012). In care facilities, this supplementation seems effective in reducing the rate of falls (Cameron et al. 2012). Home hazard assessment and modification interventions also appear effective in reducing rate of falls and risk of falling especially in people at higher risk of falling (Gillespie et al. 2012). Gradual withdrawal of psychotropic medication reduce rate of falls but not risk of falling (Gillespie et al. 2012). Also a reduction in the total number of medications should be pursued (The American Geriatrics Society 2010).

There is insufficient evidence to recommend vision intervention as a single intervention but in older women in whom cataract surgery is indicated it can reduce the risk of falling (The American Geriatrics Society 2010). Wearing suitable shoes should be advised for older people to prevent falls (The American Geriatrics Society 2010) and anti-slip shoe devices can reduce the rate of falls in icy conditions (Gillespie et al. 2012). A multifaceted podiatric care can also be effective (Spink et al. 2011). Cardiac pacing should be considered for older persons with

cardioinhibitory carotid sinus hypersensitivity who experience falls (The American Geriatrics Society 2010).

2.5 Prevention of fall-induced injuries

Although it is important to prevent falls in general, it is particularly important to prevent those falls that have serious consequences such as fractures. Prevention and treatment of osteoporosis (defined as BMD 2.5 standard deviations or more below the average value for young healthy women) is one specific way to prevent bone fractures (Current Care Guideline 2006). Briefly, the aim is to maximize peak bone-mass and prevent bone loss by exercise, calcium and vitamin D supplementation. Occasionally, osteoporosis treatment with medication (for example, bisphosphonates and hormone replacement therapy) may be needed (Kannus et al. 2005d; Current Care Guideline 2006).

Exercise interventions significantly reduced the risk of all injurious falls, falls resulting in medical care, severe injurious falls, and especially falls resulting in fractures among community dwelling older adults (Gillespie et al. 2012; El-Khoury et al. 2013). Also, it seems that exercise reduces the severity of the injuries caused by falls (El-Khoury et al. 2013). Thus, exercise training seems important and feasible means of preventing fractures and other serious injuries in elderly people, as it reduces the risk of falling and improves protective responses during a fall (El-Khoury et al. 2013). This can be achieved cost-effectively (Kannus et al. 2005d).

Previous research has indicated that multifactorial intervention can reduce falls but there has been a lack of evidence of their effectiveness in preventing fall-induced injuries (Gates et al. 2008). However, a recent multifactorial center-based Chaos Clinic Falls Prevention Program in Tampere, Finland showed almost 30% reduction in rate of falls and related injuries in home-dwelling older adults (Palvanen et al. 2014). Nevertheless, the exact reasons for the reduction were difficult to assess as the intervention included many single components whose ability in falls prevention is evidence-based (Palvanen et al. 2014).

Injury-site protection is one way to prevent fall-induced injuries. Typically, hip fracture is the result of a sideways fall and subsequent direct impact on the greater trochanter of the proximal femur (Parkkari et al. 1999). Therefore, specially designed external hip protectors (that is, shorts with padding and a shield at the lateral sides of the hip) were developed. A randomized controlled study showed that hip fracture risk reduction of more than 80% could be achieved if the

protectors were worn at the time of the falling (Kannus et al. 2000; Kannus et al. 2005e). Thus, hip protectors can be recommended for high-risk frail older adults, especially for those who have fallen before. The most usual problem with hip protectors is compromised user compliance and adherence (Kannus et al. 2005e).

Head protection could be a way to prevent fall-induced TBI, since in many sports events, such as motorcycling and bicycling, the use of a helmet is effective in prevention of head injuries (Kannus et al. 2005d). However, among older adults with a high frequency of cognitive impairment and dementia questions on ethics and effectiveness of regular helmet wear have not been resolved (Kannus et al. 2005d).

Efforts have also been made to improve the home safety of older people in order to reduce fall-induced TBI, for example with novel softer flooring (Wright and Laing 2012). Also, a recent study suggests that implementation of evidence-based fall-prevention practices may also reduce hospitalizations of fall-induced TBI (Murphy et al. 2013). Nevertheless, there is a paucity of information regarding prevention of fall-induced TBI in older adults.

After a fall has occurred, a frail older person might be unable to get up without help. Prolonged lying down can increase the severity of the injury and impair the recovery process and this can possibly be prevented via a safety phone or wristband alarming system (Honkanen et al. 2008).

2.6 Study background

The research group at Injury and Osteoporosis Research Center of the UKK Institute for Health Promotion Research in Tampere, Finland has published many studies on the secular trends of fall-induced injuries and deaths of older adults in Finland (Kannus et al. 2005a; Kannus et al. 2005b; Kannus et al. 2005c; Kannus et al. 2006; Kannus et al. 2007a; Kannus et al. 2007b). However, the latest changes in the new millennium have not been reported systematically, and therefore, the purpose of this thesis work was to follow and update these trends.

3 AIMS OF THE STUDY

The general aim of this doctoral thesis was to describe the epidemiology and trends in fall-induced deaths and injuries of older adults in Finland from early 1970s to present day. More specifically, the purpose was to determine the latest changes in the number, incidence and age-adjusted incidence of deaths and injuries due to falls in the new millennium using statutory register data. Similarly, the latest changes in the most severe fall-related injury types (hip fractures, head injuries and cervical spine injuries) were evaluated.

The specific research questions were:

1. What are the secular trends in overall unintentional injury mortality rates in Finland and how does the incidence of fall-induced deaths appear in the light of these numbers? (Study I and II)
2. How has the incidence of all fall-induced injuries changed in the new millennium? (Study III)
3. What are the current trends in the incidences of the most severe fall-induced injuries of older adults, including hip fractures (Study IV), severe head injuries (Study V), and cervical spine injuries (Study VI)?
4. What is the prediction for the future for fall-induced deaths and injuries in Finland? (Studies II-VI)

4 MATERIALS AND METHODS

4.1 The Official Cause of Death Statistics

The data on all unintentional injury deaths and fall-induced deaths for Studies I (1971-2008) and II (1971-2009) were drawn from the Finnish Official Cause-of-Death Statistics (OCDS), which are based on data in death certificates (Official Statistics of Finland 2012a). Since 1936 each death certificate in Finland has been filed in the archives of Statistics Finland (Statistics Finland 2011). The Finnish OCDS contain data amongst other things on age, gender, and place, cause, circumstances and time of death of the deceased. The annual OCDS cover all persons whose domicile is in Finland and who died during the calendar year (Statistics Finland 2011).

In Finland, the way to determine the cause of death of the deceased is defined in the law (1973/459) (Official Statistics of Finland 2012c). The Finnish OCDS are compiled according to the underlying cause of death (Statistics Finland 2011) which is the cause of events leading to death (Stakes 1995). According to the World Health Organization (WHO) the underlying cause of death is “the disease or injury which has initiated the series of illnesses leading directly to death, and/or the circumstances connected with an accident or an act of violence which caused the injury or poisoning leading to death” (Stakes 1995).

The correctness of each Finnish death certificate (issued by the physician who certified the death) is checked by a forensic pathologist at the National Institute for Health and Welfare (Official Statistics of Finland 2012c). Simultaneously, in Statistics Finland the corresponding person information of the deceased is cross-checked using our computerized population register (Population Register Center) (Statistics Finland 2011). In addition, if the category of death is not a disease but an accident, suicide, homicide or the category is unclear, the death has to be reported to local police. This leads to forensic medical detection of the death, which in practice means that a forensic pathologist will determine the cause of death after all the information acquired from the medico-legal autopsy is complete (Official Statistics of Finland 2012c). This further confirms the correctness of the death certificates and the cause of death codes in injury deaths.

All the above-mentioned procedures make the Finnish OCDS in practice 100% complete and very accurate and thus reliable source for epidemiologic research (Lahti and Penttilä 2001; Official Statistics of Finland 2012c).

4.2 The Finnish Hospital Discharge Register

The data on fall-induced injuries for Studies III-VI (1970-2011) were obtained from the Finnish Hospital Discharge Register (FHDR). The data acquisition for public health care is based on the law (556/1989) and statute (774/1989) (THL 2012). The FHDR has been computer-based since 1967 (THL 2012). Since 1994 the Hospital Discharge Register has been replaced with its modification entitled the Care Register for Health Care, which contains even more comprehensive data than its predecessor (National Institute of Health and Welfare 2013).

The FHDR contains data on patient's age, sex, place of residence, hospital number and department, day of admission and discharge, place and cause of injury, primary and secondary diagnoses, and place of further treatment. Especially, all hospital admissions leading to a stay on the ward (either in a hospital or health center) are recorded (THL 2012).

The FHDR has been compiled according to the International Classification of Diseases which has been updated many times since the first classification in 1948. The latest 10th revision of the International Classification of Diseases (ICD-10) has been in use in Finland since 1996 (Stakes 1995). Although the ICD classifications have changed during decades, the contents have remained substantially the same. Furthermore, in our studies the data inclusion criteria has remained the same for the entire study period 1970-2012.

The FHDR contains reportedly reliable data on hospital-treated injuries (Keskimäki and Aro 1991; Sund 2012). The register has been shown to cover injuries very well with excellent accuracy. Concerning severe injuries, its annual coverage and accuracy are 90% or over (Mattila et al. 2008). This makes the FHDR a reliable source of information for epidemiologic time trend analyses.

4.3 Study methods

4.3.1 Fall and injury definition

In Study I, all unintentional injuries in Finland were included. The categories of death from unintentional injury were road traffic crash, water traffic crash, fall, drowning, alcohol poisoning and other poisoning. In addition, we examined more closely the category of non-alcohol poisoning deaths. It included deaths due to overdoses of illegal and legal drugs (taken for nonmedical reasons), and poisoning deaths due to legal drugs taken in error or at wrong dose. Although of general interest, this part of the Study I is out of the further scope of this thesis.

In all later Studies II-VI the injury was caused by a fall. The extrinsic diagnose code of a fall (that is, the cause of the injury) is W00 - W19 in the current version of ICD classification, ICD-10. The data in Study II included people who died due to a fall. In Study III, a fall-induced injury was defined as an injury occurring as a consequence of a fall from a standing height of 1 m or less and resulting in hospital admission. Only the primary treatment of the first fall injury was taken into account each year over the period and therefore in this Study III one person was counted only once.

In all the specific injury types (Studies IV-VI) the injury was caused by a fall, led to a hospital admission and concerned only the primary treatment of an acute event. In Study IV, the hip fractures were identified by assessing primary and secondary diagnoses in the code class S72 (Table 1). For each observation year, one person was counted only once. In Study V, only severe hospital-treated head injuries were included and were defined as traumatic brain injuries (TBI). In Study VI, a cervical spine injury was defined as a fracture, cord injury, or their combination (Table 1). Cervical spine injuries caused by vehicular crashes or other high energy traumas were excluded, as were cases with codes identifying sequelae of previous injuries or their orthopedic or neurologic aftercare.

Table 1. The ICD-10 codes used in this thesis to define hip fractures, TBI and cervical spine injuries.

Study IV - Hip fractures	Study V - Traumatic brain injuries
S72.0 Fracture of the neck of the femur	S02.0 Cranial vault fracture
S72.1 Pterochanteric fracture of the femur	S02.1 Basal skull fracture
S72.2 Subtrochanteric fracture of the femur	S06.0 Concussion of the brain
S72.8 Fracture of some other part of the femur	S06.1 Traumatic cerebral edema
S72.9 Unspecified fracture of the femur	S06.2 Diffuse brain injury
	S06.3 Focal brain injury
Study VI - Cervical spine injuries	S06.4 Traumatic epidural hemorrhage
S12.0 Fracture of the atlas	S06.5 Traumatic subdural hemorrhage
S12.1 Fracture of the of the axis	S06.6 Traumatic subarachnoid hemorrhage
S12.2 Fracture of another cervical vertebra	S06.7 Intracranial injury and prolonged unconsciousness
S12.7 Several fractures of cervical vertebra	S06.8 Other intracranial injury
S12.9 Unspecified fracture of cervical vertebra	S06.9 Unspecified intracranial injury
S14.0 Injury of the cervical spinal cord and edema	S07 Crushing injury of the head
S14.1 Other or unspecified injury of the cervical spinal cord	S09.7 Several head injuries
S14.2 Nerve root injury of the cervical spine	S09.8 Other head injury
	S09.9 Unspecified head injury

4.3.2 Finnish population, population projections, and age definitions

The annual Finnish population denoted to the mean population in each study year. The overall injury mortality data in Study I were drawn from the entire 15-year-old or older population of Finland (Official Statistics of Finland 2013b), which was 3 504 845 in the beginning of the study period in 1971 and 4 420 523 at the end of the study period in 2008. In the following Studies II-VI the population was limited to older adults. In Study II, the 50-year-old or older population was investigated. It was 1 154 968 persons in 1971 and 2 058 770 persons in 2009.

Concerning our studies of hospital-treated fall-induced injuries, the age limit was 50 years in Studies IV and VI and 80 years in Studies III and V. The 80-year-old or older population of Finland was 50 943 in 1970 and 242 880 in 2009.

The estimated population of Finland in 2030 (Official Statistics of Finland 2012b) was used when predicting the number of fall-induced deaths and injuries in the future. If the population evolves as predicted, by 2030 the size of the 50-year-

old or older population will be 2 521 647 and the size of the 80-year-old or older population 530 442.

4.3.3 Statistical methods

In all studies the number, crude incidence (per 100 000 persons) and age-adjusted incidence of injuries were calculated for each study year. Age-adjusted incidence indicated the number of cases per 100 000 persons per year when the age structure of the population was kept unchanged during the reference period (Official Statistics of Finland 2012c). The age-adjustment was performed separately for men and women by means of direct standardization using the mean target population between study years as the standard population.

The age-adjustment procedure eliminates the changes in the statistics due to aging of the population structure and thus enables direct incidence comparisons between years and decades. In other words, age-adjustment highlights the true changes in the phenomenon in question (average individual risk for injury) by eliminating the secular demographic changes in the population.

In Studies II-VI the cases were classified by age, and the age-specific injury rates were calculated for the age groups as specified in each particular study. Also, the mean age of injury patients was calculated. In Study VI, a younger reference group, patients aged between 20 and 49 years, were used for data validation and comparison.

When appropriate, a linear regression model was used to predict the age-specific rates until the year 2030, and then, within each age and sex group, the predicted absolute number of injuries was obtained by multiplying the incidence by the estimated population, the latter being obtained from the Finnish Population Projects (Official Statistics of Finland 2012b).

In all Studies I-VI, the data were drawn from the entire population of Finland and the absolute numbers and incidences of cases were not cohort-based estimates but true descriptions of the entire Finnish population. Therefore, Studies I-VI did not use statistical analyses with confidence intervals and p-values inherently needed in cohort or sample-based estimations.

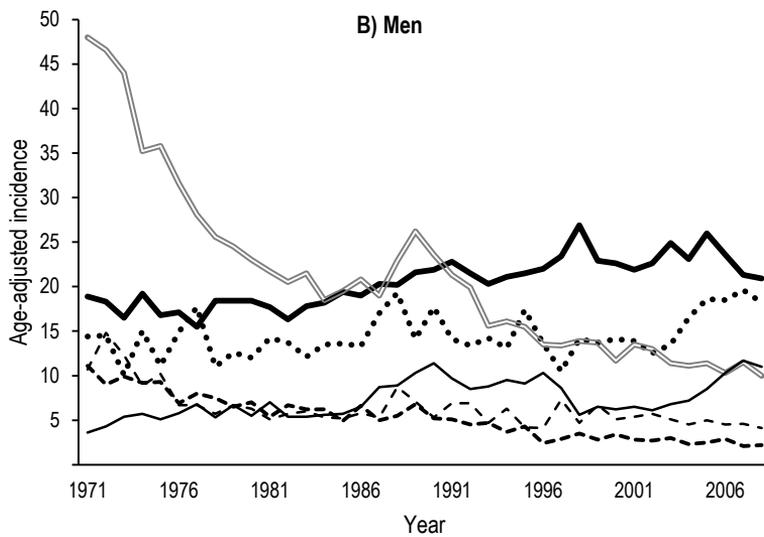
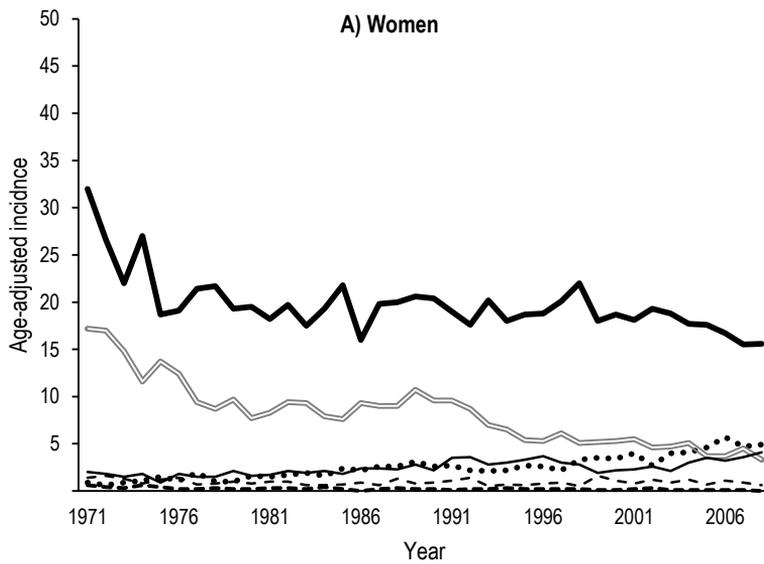
5 RESULTS

5.1 Injury deaths in Finland (I, II)

5.1.1 All unintentional injury deaths (I)

Among Finnish women 15 years of age or older, falls were the leading cause of unintentional injury death for the entire study period 1971-2008 (Figure 2A). Traffic caused fewer deaths in women than men and the incidence declined during the entire period. In 2005, alcohol poisoning surpassed road traffic crashes as a cause of women's injury death. The age-adjusted incidence of women's non-alcohol poisoning deaths also rose.

Among Finnish men, a drastic decline in injury deaths caused by road traffic crashes occurred between 1971 and 2008 (Figure 2B). On the contrary, the number of men's fall-induced deaths steadily increased during this period, falls being the leading category of men's unintentional injury death at the end of the study period. The number and age-adjusted rate of men's unintentional alcohol poisoning deaths rose, especially since 2003, and became the second leading cause of men's injury death. In the latest years of the study, the age-adjusted incidence of non-alcohol poisoning deaths also increased considerably and surpassed road traffic crashes as a cause of men's injury death.



— Falls ····· Alcohol poisonings
 — Road traffic crashes — Other poisonings
 - - - Water traffic crashes - - - Drownings

Figure 2. Age-adjusted incidence (per 100 000 persons) of unintentional injury deaths in Finland among A) women and B) men 15 years of age or older in 1971-2008.

5.1.2 Fall-induced deaths (II)

Fall-induced deaths were investigated in Finnish adults 50 years of age or older between 1971 and 2009. The overall number of deaths rose from 441 in 1971 to 1 133 in 2009.

Among Finnish women, the number of fall-induced deaths increased till the beginning of the new millennium but stabilized thereafter (Table 2). The majority (approximately 75%) of fall-induced deaths occurred in women 80 years old or older. The incidence of women's fall deaths declined during the study period and was deepest in the oldest age group, although a similarly declining trend was also seen in the younger age groups of women (Table 2). Women's age-adjusted incidence of fall-induced deaths also declined during the entire study period, the incidence being 77.2 (per 100 000 persons) in 1971 while only 35.3 in 2009 (Figure 3).

Among older Finnish men, the number of deaths due to falls increased 287% between the years 1971 and 2009 (Table 2). The annual number of fall-induced deaths was higher in men than women since 2003. Approximately 40% of men's fall-induced deaths occurred in the oldest age group (80 years or older) but the incidence also increased in the younger age groups of men (Table 2). Men's age-adjusted incidence increased from 43.4 (per 100 000 persons) in 1971 to 57.9 in 2000, but stabilized thereafter (57.3 in 2009) (Figure 3). Since 1986, this incidence has constantly been higher in men than women.

Table 2. Number and age-specific incidence (per 100 000 persons) of fall-induced deaths in Finland among people 50 years old or older in 1971-2009.

Year	Women					Men				
	N	Age group				N	Age group			
		50-59	60-69	70-79	80-		50-59	60-69	70-79	80-
1971	279	2.2	13.7	65.8	418.7	162	13.5	22.4	63.5	300.2
1975	203	1.8	7.1	44.6	257.9	165	10.9	24.9	63.2	233.7
1980	262	2.4	9.3	42.6	255.7	220	17.9	25.8	59.1	304.6
1985	375	4.4	6.3	37.8	335.5	261	14.0	20.1	78.2	338.8
1990	423	4.1	10.1	46.6	286.6	320	18.8	29.4	60.6	375.2
1995	441	4.1	6.6	44.5	269.6	352	24.5	31.6	71.2	286.0
2000	499	5.5	10.5	39.7	285.6	469	23.2	38.3	82.1	378.2
2005	526	4.9	9.8	41.9	260.0	630	34.1	49.5	86.0	382.8
2009	506	4.4	8.7	32.9	229.8	627	24.5	30.9	80.7	394.1

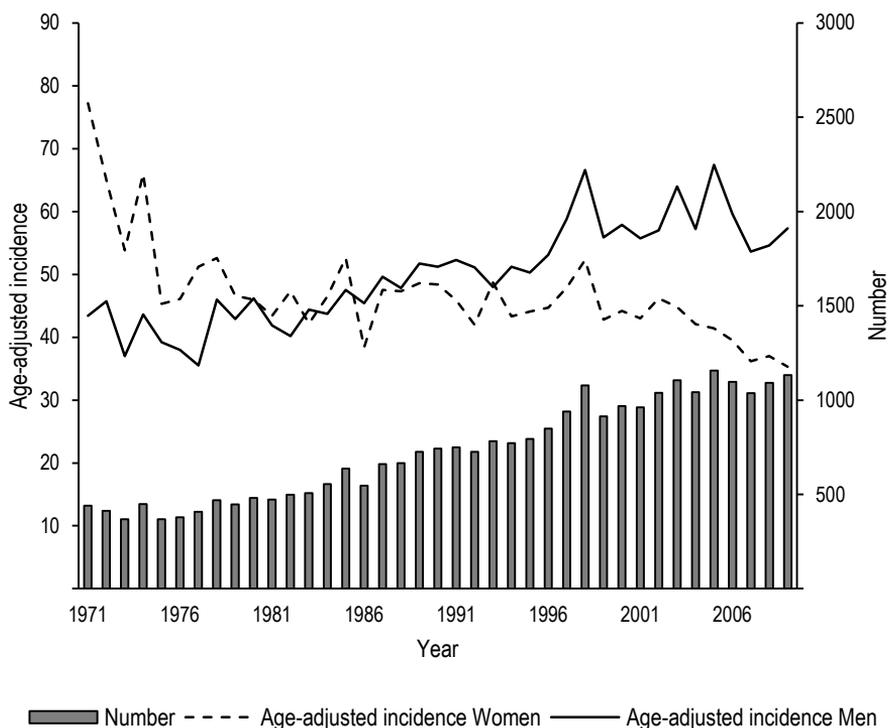


Figure 3. Number and age-adjusted incidence (per 100 000 persons) of fall-induced deaths in Finland among people 50 years old or older in 1971-2009.

5.2 Fall-induced injuries among older Finns (III)

The number of fall-induced injuries among Finns aged 80 years or older increased considerably during the study period, from 1 139 in 1970 to 13 591 in 2009 overall (a 12-fold rise). Among women, the number of fall-induced injuries rose 11-fold and among men 15-fold (Table 3). The injury incidence is higher in women than men in all age groups and in both genders the incidence increases with age (Table 3).

The age-adjusted incidence of fall-induced injuries decreased in both genders since the late 1990s (Figure 4). In 1970, the age-adjusted incidence was 2 729 (per 100 000 persons) in women and rose clearly till the year 1997 (incidence 7 079). Thereafter, the incidence started to decline and the age-adjusted incidence was 5 930 in 2009. Among men, the age-adjusted incidence rose from 1 455 in 1970 till year 1998 (incidence 5 467), but also declined thereafter, the incidence being 4 240

in 2009. Findings concerning the age-specific incidences were similar: since the late 1990s incidences of fall-induced injuries have levelled off and even started to decline among both genders and all age groups, except among the oldest old of men (Table 3).

Table 3. Number and age-specific incidence (per 100 000 persons) of fall-induced injuries in Finland among people 80 years old or older in 1970-2009.

Year	Women				Men			
	N	Age group			N	Age group		
		80-84	85-89	90-		80-84	85-89	90-
1970	927	2308.4	3280.6	3512.3	212	1122.1	1742.3	3269.8
1975	1396	2778.2	3761.8	4997.6	335	1489.7	2556.7	2985.1
1980	2312	2929.8	5174.2	7135.8	574	1911.8	3093.9	6043.0
1985	3691	3852.9	5134.7	8046.6	873	2495.1	2999.2	6529.8
1990	5236	4419.9	6064.0	6881.0	1162	2446.0	3818.7	5667.1
1995	7655	5224.4	7770.8	9382.8	1968	3735.9	5112.8	7307.6
2000	8677	5300.7	7903.1	10307.8	2337	4096.0	5758.6	7652.5
2005	9310	4914.4	7336.1	9440.3	2893	3961.6	5897.3	7994.4
2009	10333	4620.3	7263.9	9277.9	3258	3227.5	5630.8	8216.3

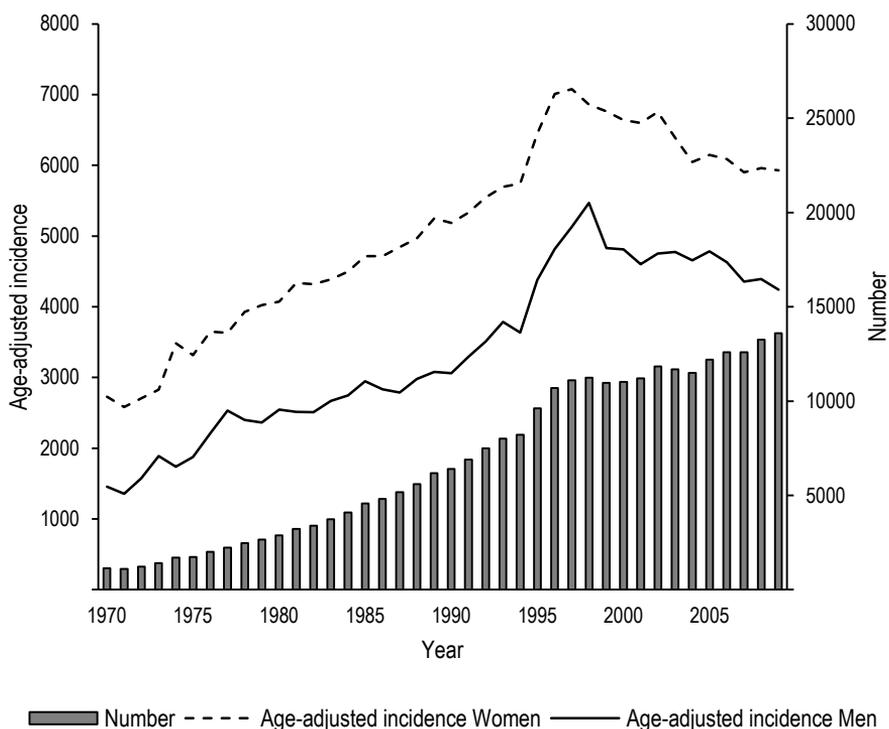


Figure 4. Number and age-adjusted incidence (per 100 000 persons) of fall-induced injuries in Finland among people 80 years of age or older in 1970-2009.

5.3 Hip fractures (IV)

As in all fall-induced injuries, there has been a change in the trend in the number and incidence of hip fractures since the late 1990s. The number of fall-induced hip fractures among Finns 50 years or older rose notably between 1970 and 1997 from 1 857 to 7 122. Since then, the rise has levelled off, the number of hip fractures being 7 594 at the end of study period in 2010. In both genders, the age-specific incidence of hip fracture has declined in the three oldest age groups since 1997 (age groups 65–74, 75–84, and 85+), while in the youngest age group (50–64 years), the incidence has remained rather stable during 1997–2010 (Table 4). In contrast with the declined fracture incidence, the average age of the Finnish hip fracture patients has risen steadily between 1970 and 2010: from 74.7 to 81.6 among women and from 70.2 to 76.0 among men.

Table 4. Number and age-specific incidence (per 100 000 persons) of hip fractures in Finland among people 50 years old or older in 1970-2010.

Year	Women					Men				
	N	Age group				N	Age group			
		50-64	65-74	75-84	85-		50-64	65-74	75-84	85-
1970	1409	54.8	237.8	750.5	2023.8	448	44.7	120.0	337.7	1071.6
1975	1609	45.0	213.7	790.3	1874.2	548	48.9	135.8	364.2	941.1
1980	2389	52.5	259.3	870.5	2926.0	750	46.8	182.1	414.7	1521.6
1985	3210	48.9	272.5	1113.5	2818.7	1010	59.2	169.4	605.8	1723.2
1990	4245	66.1	292.6	1334.4	3088.6	1304	70.5	213.1	645.4	1992.4
1995	4900	59.2	332.9	1373.8	3340.7	1555	68.3	228.5	753.2	2019.0
2000	5198	54.7	284.8	1289.9	3397.8	1953	78.0	236.5	768.5	2472.2
2005	5049	59.1	246.7	1143.1	2958.8	2064	74.6	214.1	721.8	2088.9
2010	5232	60.2	240.9	1015.1	2746.9	2362	82.5	196.9	684.1	1995.6

In women as well as in men, the age-adjusted incidences of hip fracture rose until 1997 but have continuously declined thereafter (Figure 5). The decline has been especially clear in women among whom the age-adjusted incidence was 515.7 (per 100 000 persons) in 1997 while only 382.6 in 2010. Among men, the corresponding incidence was 245.3 in 1997 and 210.7 in 2010. Throughout the study years the age-adjusted incidence of hip fractures has been clearly higher in women than men.

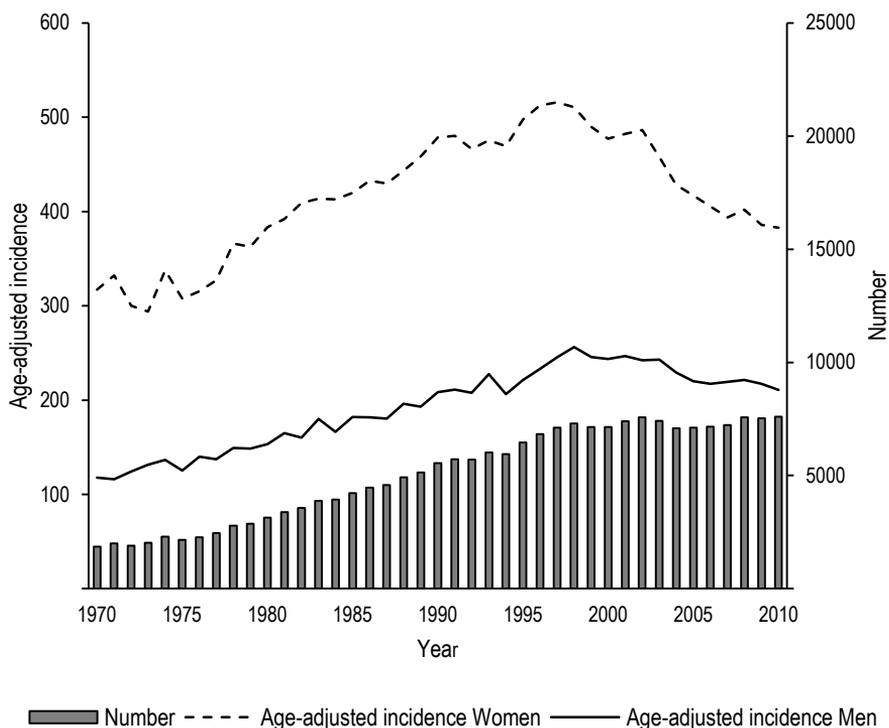


Figure 5. Number and age-adjusted incidence (per 100 000 persons) of hip fractures in Finland among people 50 years of age or older in 1970-2010.

5.4 Traumatic brain injuries (V)

The overall number of Finns 80 years or older with a fall-induced TBI increased considerably from 85 in 1970 to 1817 in 2011. The age-specific incidence of TBI rose in all age groups and especially among the oldest old (Table 5). Although the number of TBI was higher in women than men, the incidences were on a fairly equal level between genders (Table 5, Figure 6). The age-adjusted incidence of TBI (per 100 000 persons) also showed a marked increase from 168.2 women in 1970 to 653.6 in 2011, and from 174.6 to 724.0, respectively, in men (Figure 6). The increase was 289% in women and 315% in men.

Table 5. Number and age-specific incidence (per 100 000 persons) of fall-induced TBI in Finland among people 80 years old or older in 1970-2011.

Year	Women			Men				
	N	Age group			N	Age group		
		80-84	85-89	90-		80-84	85-89	90-
1970	60	170.4	170.9	150.5	25	160.3	56.2	681.2
1975	98	206.7	267.4	227.2	31	84.0	414.6	205.9
1980	115	167.1	240.5	220.2	48	137.4	325.7	509.6
1985	195	212.1	272.1	359.2	67	228.6	160.0	368.6
1990	306	276.6	279.4	500.1	147	313.8	398.7	975.8
1995	451	317.0	456.5	508.6	166	340.3	473.6	257.9
2000	653	382.4	594.8	839.5	248	415.5	626.4	883.8
2005	832	388.7	708.1	932.1	356	493.0	691.1	1038.9
2011	1205	492.5	845.5	970.1	612	608.0	886.5	1141.7

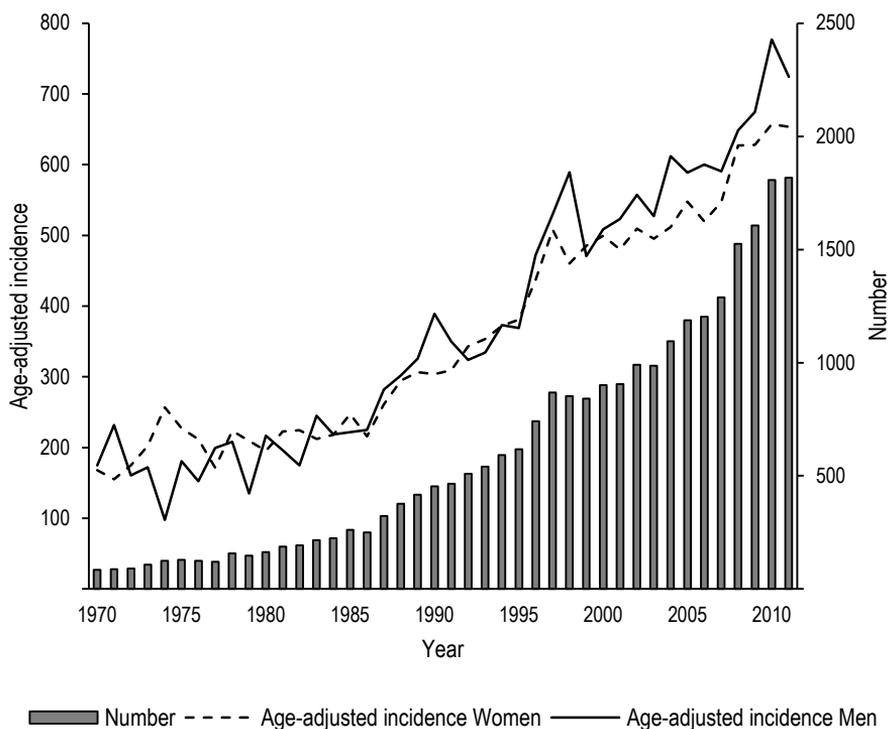


Figure 6. Number and age-adjusted incidence (per 100 000 persons) of fall-induced TBI in Finland among people 80 years old or older in 1970-2011.

5.5 Cervical spine injuries (VI)

The number of a fall-induced cervical spine injury among 50 year old or older Finns rose considerably between the years 1970 and 2011, from 59 in 1970 to 372 in 2011. The number of injuries was higher in men than women and the increase in incidence was most prominent in the oldest age groups (Table 6). The average age of a patient having a fall-induced cervical spine injury in this population increased from 1970 to 2011: from 62 years to 71 in men, and from 65 to 79 in women. Throughout the study period, the age-adjusted incidence of injury (per 100 000 persons) was higher in men than women and showed a clear increase from 1970 to 2011: from 8.5 to 20.3 in men, and from 2.8 to 11.7 in women (Figure 7).

Table 6. Number and age-specific incidence (per 100 000 persons) of fall-induced cervical spine injuries in Finland among people 50 years old or older in 1970-2011.

Year	Women					Men				
	N	Age group				N	Age group			
		50-59	60-69	70-79	80-		50-59	60-69	70-79	80-
1970	18	2.6	2.1	3.2	5.6	41	6.9	10.0	12.9	0.0
1975	26	2.9	2.7	5.3	6.8	54	9.5	9.4	19.1	0.0
1980	32	3.1	2.4	5.5	11.5	64	10.4	10.0	16.0	21.2
1985	38	1.5	2.0	9.0	13.6	61	9.3	10.6	11.8	16.4
1990	39	1.9	4.1	5.6	11.7	65	8.4	10.6	14.9	12.9
1995	64	4.1	1.2	8.6	26.2	70	5.3	10.1	15.9	31.3
2000	67	3.6	3.9	7.9	20.5	98	9.4	13.2	12.4	33.8
2005	104	3.0	6.2	12.9	31.1	184	13.8	19.0	32.4	46.8
2011	155	3.4	4.5	16.4	49.9	217	9.3	20.4	32.2	67.3

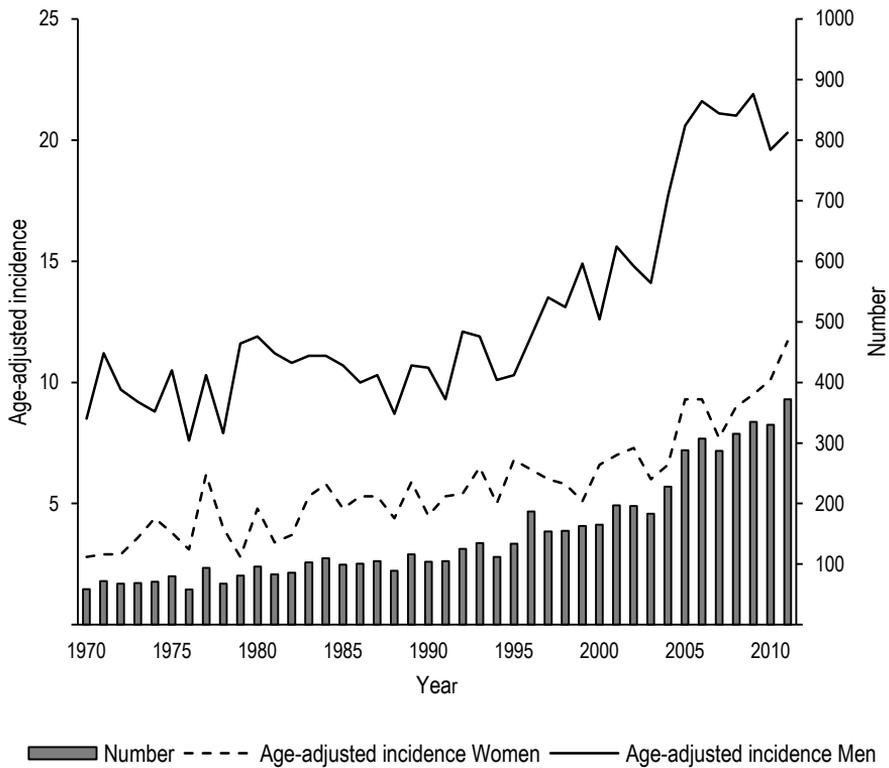


Figure 7. Number and age-adjusted incidence (per 100 000) of fall-induced cervical spine injuries in Finland among people 50 years old or older in 1970-2011.

In the younger reference group aged 20-49 years, the annual number and age-adjusted incidence of cervical spine injury decreased slightly over time: in 1970, the number and incidence were 85 and 4.5, respectively, and 65 and 3.2 in 2011. Across the study period, male predominance was clear in this age group, too: 79% and 77% of the patients were men in 1970 and 2011, respectively.

5.6 Up-to-date data

Currently, the Injury and Osteoporosis Research Center at the UKK Institute has up-to-date injury data till the end of 2012. The number of fall-induced deaths has remained the same in latest years following the end of the study period in the Study II. Among Finnish women, 541 fall-induced deaths occurred in 2012 and the number has been constantly higher in men (575 fall-induced deaths in 2012). The

age-adjusted incidence has slightly declined in both genders: in 2012 the incidence (per 100 000 persons) was 34.8 in women and 48.8 in men.

The overall number of hospital-treated fall-induced injuries increased in recent years and the number of injuries was 14 693 in 2012. The decline since the late 1990s in the age-adjusted incidence of fall-induced injuries still continued: in 2012 the incidence was 5 854 among women and 4 084 among men.

The annual number of hip fractures has remained the same in recent years: in 2012 there were 7 585 hip fractures in Finland in persons 50 years of age or older. The decline in age-adjusted fracture incidence continued. In 2012 the incidence was 372.3 (per 100 000 persons) among women and 193.5 among men. On the other hand, the average age of a hip fracture patient rose: in 2012 the average age among women was 81.8 and among men 76.6.

In contrast to the numbers and trends described above, the number and age-adjusted incidence of TBI and cervical spine injury rose again in the year following our latest reports. In 2012, the number of TBI in Finns 80 years or older was 1 980 and the age-adjusted incidence was 694.8 among women and 759.4 among men. In 2012 the number of cervical spine injuries was 434 in Finns 50 years or older and the age-adjusted incidence was 13.0 among women and 23.7 among men.

Figure 8 shows comparison between the crude incidence of hip fracture and TBI among Finns 80 years of age or older in 1970-2012. Since the end of the 1990s, the curves have started to approach each other.

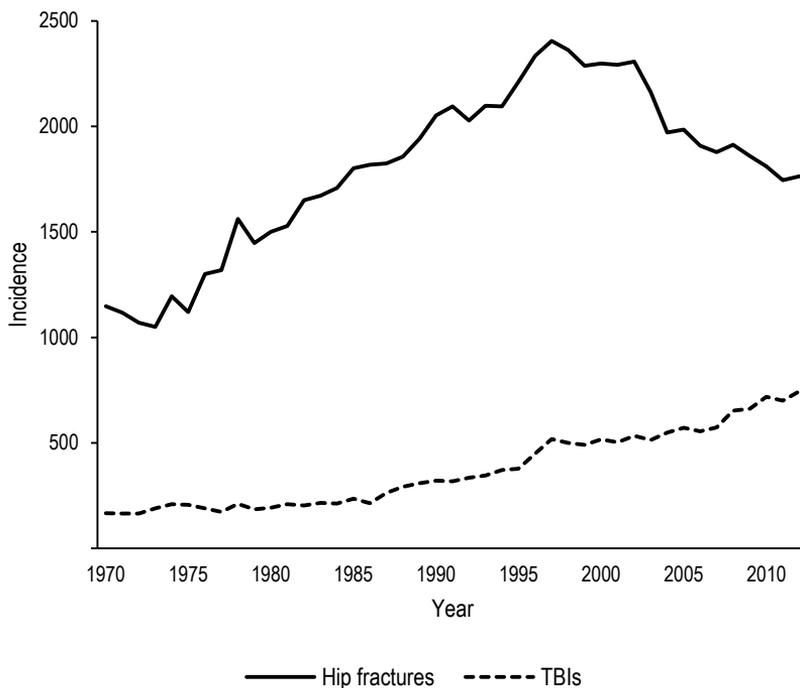


Figure 8. Incidence (per 100 000 persons) of fall-induced hip fractures and TBIs in Finland among people 80 years of age or older in 1970-2012.

5.7 Prediction for the future

According to the latest data, if the age-specific incidence of fall-induced deaths continues to develop at the average rate observed between 1970 and 2012 and the size of the 50-year-old or older Finnish population increases as predicted (from 2.1 million in 2012 to 2.5 million in 2030) the number of deaths would double by the year 2030 even with the observed declining incidences in women. According to this prediction, there would be 2 240 fall-induced deaths in Finland in 2030 compared with 1 116 deaths in 2012.

If the age-specific incidence of all fall-induced injuries continues to rise at the average rate observed between 1970 and 2012 and the size of the 80-year-old or older population of Finland increases as predicted (from 266 005 in 2012 to 507 549 in 2030), the number of these injuries will be 2.9-fold higher in 2030 (41 961 injuries) than in 2012 (14 693 injuries) (Figure 9, curve A). However, if we assume that the incidence remains at the 2012 level, the number of fall-induced

injuries would be only 1.9-fold higher by the year 2030 (27 554 injuries) compared with the year 2012 (Figure 9, curve B). Finally, should the incidence continue to decline at the average rate observed since the late 1990s, the absolute number of these injuries would still increase during the coming decades (1.4-fold rise resulting in 21 042 injuries in the year 2030) (Figure 9, curve C).

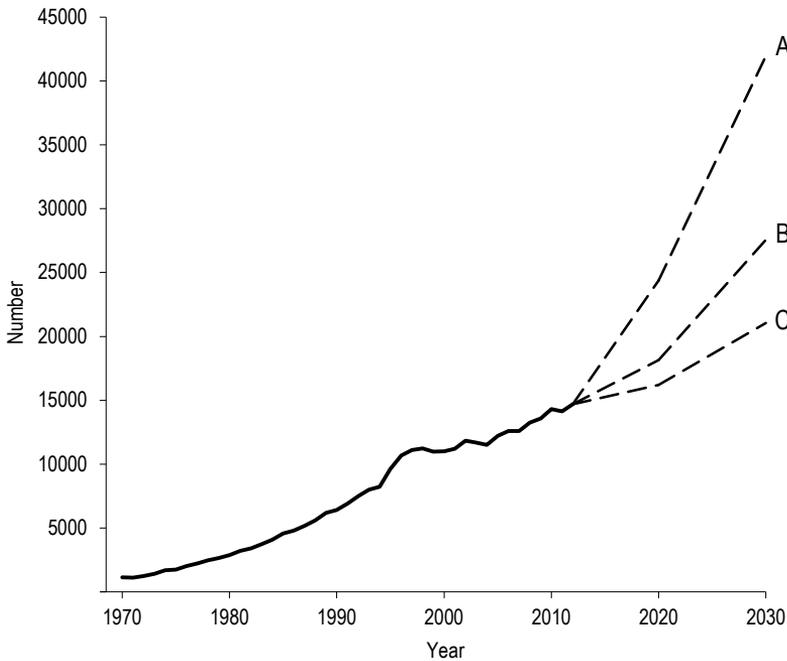


Figure 9. The number of fall-induced injuries in Finland among people 80 years old or older in 1970-2012 and predictions for the future. Curve A is made assuming that the age-adjusted incidence of fall-induced injuries continues to develop at the average rate observed during 1970-2012. Curve B indicates prediction in which the incidence stabilizes to the 2012 level. Curve C denotes to prediction in which the incidence continues to decline at the average rate observed since the late 1990s.

If the above noted decline in hip fracture incidence continues, the number of these injuries can even slightly decrease in the future. Assuming that the size of the 50-year-old or older Finnish population increases as predicted and the incidence continues to decline at the average rate observed since 1998, the number of hip fractures would decrease to about 6 700 fractures per year by the year 2030. If however, the incidence of fractures is to become stabilized to the current 2012 level, the number of hip fractures will increase in Finland between 2012 and 2030, up to about 12 300 annual hip fractures by the year 2030.

If the age-specific incidence of TBI (among 80-year-old or older population) and cervical spine injuries (among 50 year-old-or older population) continues to rise at the average rate observed between 1970 and 2012, the number of TBI would be 2.4-fold higher (4 752 injuries) and the number of cervical spine injuries 1.4-fold higher (611 injuries) in 2030 than in 2012.

6 DISCUSSION

This thesis study described the epidemiology and trends in fall-induced deaths and injuries of older adults in Finland using reliable statutory register data since the early 1970s. The focus was especially on the latest changes in the new millennium. One of the main observations was that during the past four decades Finland has experienced a drastic change in the profile of unintentional injury deaths with falls and poisonings replacing road traffic crashes as the leading causes of injury deaths. Also, the profile of severe fall-induced injuries of older adults has changed since the late 1990s with the incidence of hip fractures declining and that of severe head injuries and cervical spine injuries continuously increasing.

Because the Finnish elderly population will grow very rapidly in the near future, the absolute number of older persons' fall-induced injuries will also increase during the coming decades. This fact is crucial for Finnish health care planning and proper management of the health care costs in the future.

6.1 Fall-induced deaths

The study showed that the number of fall-induced deaths among older adults in Finland has increased, especially among men. In recent years, both the number and the age-adjusted incidence (that is, the average individual risk) of fall-induced deaths have been higher in men than women. On the other hand, among women the incidence of fall mortality declined during the study period. Also among men, the rise in incidence levelled off in the most recent years of observation.

The burden of fall-induced deaths is expected to increase in the future. By the year 2030 the number of fall-induced deaths may double among older Finns because of aging of our population. According to population projections and the results of this study, the gender difference in the absolute number of these deaths could accentuate in the future for at least two reasons. Firstly, in men the age-adjusted incidence of falls mortality has not clearly decreased while in women the incidence has declined continuously. Secondly, the number of older men in our population is expected to rise more rapidly than that of women. At the beginning

of the study period in 1971 the female/male ratio in the Finnish population aged 50 years or older was 1.42. By 2009 this ratio declined to 1.18 and in 2030 the predicted ratio is 1.14 (Korhonen et al. 2013).

The data for fall-induced deaths can be considered very reliable as they are obtained from the statutory register of Finnish OCDS. As described earlier, the OCDS are in practice 100% complete and the injury deaths discussed are almost invariably further examined with forensic medical detection and medico-legal autopsy. In addition, the strength of this study is the long follow-up with unchanged definition of falls and related deaths (Official Statistics of Finland 2012c).

A limitation in our and other studies of fall-induced mortality of older adults is the probable underreporting of these deaths (Betz et al. 2008). A patient may die of late complications of an injury. Therefore, the attending physician may not be fully aware of the original injury which resulted in the chain of morbid events and finally death. Actually, most fall-induced deaths are not immediately fatal. Survival times after the accident can be up to one year (Thierauf et al. 2010), although most of these deaths (around 90%) occur within the first two months after the injury (Fleischman et al. 2010). For example, underreporting has been found in deaths following hip fractures. It was found that even when the death occurred within 28 days of the recorded hip fracture, the fracture was not mentioned on the death certificate in almost 50% of the cases (Hindmarsh et al. 2009). In the Finnish 2012 statistics, falls were recorded as a contributing factor (not the underlying cause of death on which the OCDS are based) in deaths of 770 older persons when the actual cause of death in the death certificate was something else (Official Statistics of Finland 2013a). Thus, the annual fall fatalities described in this study are accurate but likely to represent only the tip of the iceberg when considering all deaths influenced at least partly by falling.

The OCDS obtained from Statistics Finland do not, unfortunately, contain information about specific injuries and traumas the deceased person sustained in his or her fall accident. Also, the specific information on the sub-mechanism of the falls, for example if the fall occurred from a bed, in a staircase or icy conditions, is available only from 1998 onwards. The coverage and accuracy of this information are not as high as the data presented in the study. Thus, already at the beginning of the project, we decided to exclude this information.

Direct comparisons between our statistics and data from other countries on numbers and rates of injury deaths, and especially fall-induced deaths, are difficult to make. Large international differences exist in availability of cause of deaths

statistics, classification of injury deaths, and practices in determination of cause of deaths. The age limits of older adults have also differed between studies. Nevertheless, long-term studies from other countries have so far reported mainly increasing rates of fall-induced deaths among older adults (Centers for Disease Control and Prevention (CDC) 2006; Orces 2008; Dowling and Finch 2009; Hu and Baker 2010; Wendelboe and Landen 2011; Alamgir et al. 2012; Stevens and Rudd 2014). Even the only report showing decreased fall mortality rates indicated stable or rising rates over the most recent decade (Hartholt et al. 2012a). The reasons for these trends have been speculative. It has even been suggested that the increase in the USA could partly be due to better reporting of falls as the cause of death (Stevens and Rudd 2014).

Therefore, the declining incidence of fall-induced deaths among older Finnish women showed in this study seems unique. This finding is in line with our observations on declining incidence of all fall-induced injuries in the new millennium. In contrast, older Finnish men have surpassed women in the rate of fall mortality and there has been only a stabilizing trend in men's fall mortality in the new millennium. However, the rate of fall-induced injuries has declined similarly among men and women in the new millennium.

The exact reasons for the disparity between sexes in fall-induced deaths are largely unknown. Many of fatal fall injuries are hip fractures (Deprey 2009; Official Statistics of Finland 2013a) and one explanation could be the excess mortality among men following hip fractures. Men have at least twice the risk of death following a hip fracture compared to women (Piirtola et al. 2008; Abrahamsen et al. 2009; Hindmarsh et al. 2009) and the excess annual mortality persists over time (Haentjens et al. 2010). The difference between sexes remains even when controlled for age, fracture site, medication, and chronic comorbidities (Kannegaard et al. 2010). It has been suggested that postoperative complications following a hip fracture, such as infection, may contribute to male excess mortality and that some comorbid conditions could be undertreated after the fracture leading to more fatal acute postoperative complications among men (Abrahamsen et al. 2009; Kannegaard et al. 2010; Haentjens et al. 2010).

Head injuries also account for many fall-induced deaths (Deprey 2009; Thierauf et al. 2010) and fatal head injuries are more common among men (Thomas et al. 2008; Chisholm and Harruff 2010). Alcohol consumption could be related to our results since alcohol appears to be an important risk factor in falls. Alcohol consumption possibly leads to more serious consequences of falling. It has been reported that 13% of the deceased in fall-induced deaths in Finland were under the

influence of alcohol at the time of the fall and that men were intoxicated more often than women (Impinen et al. 2008). Moreover, a German study reported that almost 60% of men fell under the influence of alcohol in retrospective analysis of fatal falls (Thierauf et al. 2010). In that study, the injury pattern with or without alcohol in case history differed: without alcohol the limbs were most often injured while with alcohol the injury occurred more often to the cranium (especially back of the head) and organs (Thierauf et al. 2010). In Illinois USA, 50% of trauma patients aged over 65 years tested positive for alcohol in the ED and most were men (Zautcke et al. 2002). Furthermore, a Finnish study conducted at a district hospital revealed that 28% of hip fracture patients were under the influence of alcohol at the time of the arrival (Nurmi-Lüthje et al. 2007).

Additionally, heavy alcohol drinking history is associated with a significantly increased risk of fatal fall among older people (Sorock et al. 2006). Around 11% of Finnish men 65 years of age or older report heavy drinking (defined as drinking 15 drinks or more per week) (Halme et al. 2010). Although alcohol consumption declines with age, nearly 20% of men aged 71-80 years and 10% aged 81-90 years can be classified as at-risk drinkers (consuming >7 drinks per week) (Immonen et al. 2011). A study from Oulu, Finland concluded that male sex and falling were associated with alcohol-related TBI and that alcohol and older age predicted fatal outcome (Puljula et al. 2013). It has also been suggested that men are more likely to engage in risky behaviors which could explain, at least to a small degree, the gender difference in fall mortality (Alamgir et al. 2012).

Finally, several factors prior the fall-injury may influence the injury outcome. These factors include low levels of physical activity, poor muscle strength and mobility (Rantanen 2003), impaired cognition, and poor nutritional status. Possibly the disadvantages of immobility emphasize more in men than women (Sievänen et al. 2014). Patients have a significant long-term excess mortality following trauma, especially if the injury is sustained from a fall, thus suggesting that trauma itself may be an indicator of long-term mortality or overall decline of the patient (Davidson et al. 2011). Associated to this, improved functional ability among Finnish women compared with men could partly explain the observed changes, though the gender differences in improvements have been relatively small (Sulander et al. 2003; Sulander et al. 2007; Laitalainen et al. 2010).

6.2 Fall-induced injuries

The current study showed that the rise in the incidence of fall-induced injuries among older Finns from the 1970s to the late 1990s was followed by declining injury rates. However, the absolute number of these injuries increased considerably during the study period 1970-2012. A fall-induced injury is clearly a gender-related and age-related phenomenon since the age-adjusted incidence is higher in women than men and the incidence increases with age (Korhonen et al. 2012).

The strengths of this study include long-term follow-up with unchanged injury definition and the coverage of the whole country using statutory register data. These strengths of FHDR are well recognized (Räisänen et al. 2013) and from an international point of view the FHDR is unique. It is the oldest nationwide discharge register in the world and covers the entire, well-defined population of Finland.

In our study III, we wanted to minimize the readmission and between-hospitals transfer problems in the statistics. In other words, we eliminated multiple counts for the same patient while treating the incident case of a fall in different facilities. Only the primary treatment period of each fall injury patient was taken into account and this meant that each year one person could only be included once. Therefore, this study identified only persons who were hospitalized due to a fall injury rather than revealed all hospitalizations and treatment periods contributing to our health care costs. Apparently, the entire burden of fall-induced injuries of older adults to the Finnish society exceeds the numbers described in this study.

In the studies III, V and VI of fall-induced injuries, we also included in the analysis cases with no FHDR information on external cause of injury. This could have resulted in slight overestimation of the annual number of injuries. On the other hand, such cases were rather rare and among older adults injuries are most often fall-induced if no information on the mechanism of injury is available (Thomas et al. 2008).

Another limitation was that we were unable to obtain detailed, accurate information on the injury location, and the type, sub-mechanism and place of the injury. This was due to the nature of the register study and the coding practices in hospitals. Register data also lacks information on reasons and risk factors for falls, and severity of injury. However, the aim of this study was to describe the overall trends in fall-induced severe injuries that are treated in hospitals and for this purpose the coverage and accuracy of the FHDR are excellent (Sund 2012; Räisänen et al. 2013).

It can be speculated that the current findings on declining incidence in fall-induced injury hospitalizations of older adults could be caused by changes in the Finnish hospitalization policy or stricter criteria for injury-based hospital admissions in the new millennium. This hardly is the explanation because similarly decreasing injury incidences have been seen in many severe fracture types, such as hip fractures and knee fractures (Kannus et al. 2009a). These serious injuries have always required admission to a hospital suggesting that the true average individual risk for fall-induced injuries of older adults is decreasing. In some types of injury, such as distal radius fractures, improved surgical techniques have actually resulted in rise in the absolute and relative number of victims taken into a hospital (Mattila et al. 2011).

The current finding on declining rate of fall-induced injuries among elderly Finns is unique since other countries have reported rising trend of these injuries (Hartholt et al. 2010; Hartholt et al. 2011b; Orces 2013; Cassell and Clapperton 2013). We recognize that our study describes national data of Finland and thus the results cannot be generalized. In general, comparing different countries in the light of incidence rates of fall injuries is problematic due to the differences in data collection, study methods, and injury definition. For example, Hartholt et al. (2011b) and Orces (2013) used the data of the National Electronic Injury Surveillance System All Injury Program. The data represented a sample of fall injuries in selected hospitals in the USA, which was then summed to produce national estimates (Hartholt et al. 2011b; Orces 2013). Another US study based the data on National Hospital Discharge Survey (which excludes certain hospitals) and an estimation of national injury hospitalizations was produced (Orces 2010).

In the above noted US studies the denominator for incidence calculations was the number of population obtained from the US Census Bureau (Orces 2010; Hartholt et al. 2011b; Orces 2013), a method which is not as reliable as the computerized population register in Finland. Also in Australia, the denominator data is based on estimate census data (Watson and Mitchell 2011). In the study from Netherlands, the national database had nearly complete coverage and the final data presented were extrapolated to full coverage (Hartholt et al. 2010). Occasionally, fall and injury data have also been collected with surveys (Stevens et al. 2008).

The readmission and between-hospitals transfer problems are likely to weaken the reliability of the database in many countries. One study attempted to eliminate multiple counts for hospitalizations due to falls using the referral source variable in order to exclude hospitalizations relating to transfers between hospitals and

changes in the service category (Watson and Mitchell 2011). Another study attempted the same with excluding transfers within and between hospitals and re-admission within 30 days (Cassell and Clapperton 2013). In many studies, the issues of readmission and between hospital transfers have not been acknowledged at all.

The definition of a fall-induced injury also varies. Although the external cause diagnoses are usually consistent, some studies included only certain principal diagnoses (Watson and Mitchell 2011; Cassell and Clapperton 2013). Therefore, direct comparisons between numbers presented in different studies are often not feasible.

The exact reasons for the recent decline in age-adjusted incidence of older adults' fall-induced injuries in Finland are unknown. One speculation is that a cohort effect towards healthier older populations might explain the positive development that has been seen in specific injury types, such as knee fractures and proximal humeral fractures (Kannus et al. 2009a; Kannus et al. 2009b) and now in fall-induced injuries in general. This concerns especially the most typical fall injuries of older adults, fractures. Early life risk factors for fractures (such as perinatal nutrition) may have had stronger effect on the fracture risk in the earlier than later birth cohorts. However, the change in 1990s from increasing to declining rates occurred rather abruptly to be fully explained with such gradual population changes.

Another explanation could be that average functional ability of elderly people in Finland has improved (Sulander et al. 2003; Sulander et al. 2007; Laitalainen et al. 2010) although among the oldest old (people aged 90 years or over) the functional ability has remained fairly similar since the mid-1990s (Jylhä et al. 2009). Functional ability and falls interrelate since the risk of falling increases with the difficulty to ambulate (Sievänen et al. 2014). Today elderly people's lifestyle could be physically more active compared with their age-mates' in earlier decades and thus improved muscle strength, balance and coordination could reduce the risk of falling (Kannus et al. 2005d; Gillespie et al. 2012).

Furthermore, changes in the environment of the older adults could partly explain the observations. Improvements in promoting safety at home and public surroundings, and more systematic use of walking aids, could have made ambulation safer and thus reduced the risk of falling.

Lastly, actions and interventions to prevent falls and consecutive injuries could have had a favorable effect to injury incidence (Kannus et al. 2005d; Karinkanta et al. 2010; Gillespie et al. 2012). These interventions include strength and balance

training, periodical medical and medication review, calcium and vitamin D supplementation, wearing of hip protectors and gait-stabilizing antislip devices, and home modification. However, as in other explanations, direct causal evidence is lacking.

The long-term statistics represented in this study on the entire spectrum of fall-induced injuries are in line with reports on some more specific injury types in Finland. For example, the rates of proximal humeral fractures (Kannus et al. 2009b) and hip fractures have stabilized or started to decline since late 1990s. However, the rate of severe injuries to the head (TBIs and cervical spine injuries) have not followed the same trend but instead increased throughout our entire study period.

6.3 Changes in the profile of specific injuries caused by falls

The current study shows that in Finland the age-adjusted incidence of hip fractures increased until 1997 but has then decreased during the entire first decade of the new millennium. The incidence of hip fractures has been higher in women than men for the entire study period and the decline has been especially clear among women. Thus, the trend in incidence of hip fracture is similar compared with that of fall-induced injuries in general among older Finns.

In contrast, the number and age-adjusted incidence of fall-induced TBI and cervical spine injuries among older Finns increased considerably throughout the study period 1970-2012 without a sign of levelling off in the new millennium. In the younger adults aged 20-49 years, such an increase in incidence of cervical spine injuries was not seen. The age-adjusted incidence of TBI was on a fairly equal level between sexes but the incidence of cervical spine injuries was higher in men than women.

These Finnish data on the incidence of hip fractures are in line with other studies from Scandinavia (Abrahamsen and Vestergaard 2010; Stoen et al. 2012; Nilson et al. 2013b), Netherlands (Hartholt et al. 2011a), Australia (Cassell and Clapperton 2013), Canada (Leslie et al. 2009) and the USA (Brauer et al. 2009; Stevens and Anne Rudd 2010; Brown et al. 2012; Adams et al. 2013). They all report declining rates of hip fracture since the late 1990s to the new millennium. On the other hand, some areas of Asia and South America have reported rising incidences of hip fractures (Cooper et al. 2011; Ballane et al. 2014).

Moreover, the findings of increasing incidence of fall-related TBI among older adults are consistent with other recent observations (Fletcher et al. 2007; Hartholt et al. 2011d; Harvey and Close 2012; Kool et al. 2013). Similarly, previous studies from different countries have reported increases in fall-induced cervical spine injuries among older adults (Brolin 2003; Devivo 2012; Mitchell et al. 2014).

As discussed earlier, direct comparisons between various countries concerning incidence rates of injuries are difficult and uncalled for because of differences in data collection, study methods, subjects' age limits, and injury definition. In data regarding hip fractures, the definition of injury is quite simple and similar between studies but the data have been collected with both audit data and register data. Both these methods have their own strengths and limitations (Sund et al. 2007). In TBIs, the injury definition varies widely. For example, Harvey and Close (2012) used a narrower and Thomas et al. (2008) a more wide-ranging definition for TBI than our current study. In the current study, cervical spine injury was defined as a fracture, cord injury, or their combination, while many other studies have covered only one of these injury types (Ahoniemi et al. 2008; Wang et al. 2013; Mitchell et al. 2014).

There are several possible explanations for the observed decline in incidence of hip fractures. One suggestion is, as for fall-induced injuries in general, that the average functional ability of elderly people in Finland has improved (Sulander et al. 2003; Sulander et al. 2007; Laitalainen et al. 2010). Thus, improved muscle strength, balance, and coordination among today's elderly people could reduce the risk of falling leading to hip fractures, compared with their perhaps physically less active age-mates in earlier decades. As women have reportedly higher incidence of injurious falls than men (Nordström et al. 2011), one may speculate whether the functional ability of women has improved more than that of men. This could account for the steeper decline in women's hip fracture incidence.

Secondly, improved prevention and treatment of chronic diseases might have affected the hip fracture incidence. For example, cardiovascular diseases have been associated with hip fractures (Sennerby et al. 2009). A recent study reported declining hip fracture incidence parallel with the declining incidence of chronic comorbidities, such as ischemic heart disease, COPD and dementia (Jorgensen et al. 2014). It was suggested that the reduction in fractures could be partly explained by reduced fall-related comorbidity (Jorgensen et al. 2014).

Thirdly, nutritional changes may have influenced the development of hip fractures. A low BMI is a strong risk factor for hip fracture, whereas a high BMI or overweight is protective (De Laet et al. 2005). This is most likely due to improved

bone and muscle strength and direct padding effect of the fat tissue on the hip. Changes in body weight could have reduced the average risk of hip fracture in Finland. The prevalence of obesity (BMI 30 kg/m² or over) has increased by 70 % in Finnish men and by 30 % in Finnish women since the 1980s and this has affected all adult age groups of the population (Aromaa and Koskinen 2004). Currently 17 % of our men and 16 % of our women are obese (Helldan et al. 2013).

Next, actions to prevent and treat osteoporosis could also partly explain the declining hip fracture incidence. More specifically, increased availability and use of BMD testing, exercise, non-smoking campaigns, calcium and vitamin D supplements, hormone replacement therapy, and bone-specific drugs could have contributed to the incidence of osteoporosis and hip fractures. This is confirmed by the observation that the mean femoral neck BMD has increased among older Finnish women within the recent decade (Uusi-Rasi et al. 2013). For example, smoking, which is a clear risk factor for hip fracture, has reduced in Finnish men from the prevalence of 35 % in 1970s to current level of 19% (Helldan et al. 2013). In Finnish women, the highest prevalence was in 1990s (20% smoked) while the current prevalence of smokers is 13 % (Helldan et al. 2013).

On the other hand, decreasing hip fracture rates were observed even before the widespread availability and use of some these methods, such as BMD testing and osteoporosis medication (Leslie et al. 2009; Brauer et al. 2009; Abrahamsen and Vestergaard 2010). A Swedish report concluded that the prevalence of osteoporosis has not changed since 1970s (Ahlborg et al. 2010). In Canada, there is a fourfold difference in prescribing osteoporosis medication across provinces, but no correlation was found between prescribing load and hip fracture rate (Crilly et al. 2014). The drug use has always concerned only a minority of the elderly population, and the pharmaceutical interventions of women (estrogen) cannot explain the declining fracture pattern in men (Leslie et al. 2009; Abrahamsen and Vestergaard 2010). It has been shown that low areal BMD and osteoporosis may not well explain the higher fracture incidence in women than men, but instead, injurious falls, which are more common among women, are associated with increased fracture risk (Nordström et al. 2011). Furthermore, over 80% of low trauma fractures occur in people who do not have osteoporosis (Järvinen et al. 2008).

Finally, the programs to prevent falling and minimize fall severity (by exercise, modification of environmental hazards, use of hip protectors, gait-stabilizing walkers and antislip shoe devices, reducing psychotropic medication, and vitamin

D and calcium supplementation) could partly explain the continuing decrease in hip fracture rates (Gillespie et al. 2012). Although the same limitations apply here as noted above for osteoporosis, these measures might be feasible for larger implementation.

It is of great interest that while the overall incidence of elderly people's fall-induced injuries and incidence of hip fractures have declined during the new millennium in Finland, the rise in the incidence of TBI and cervical spine injuries is steep and ongoing. The reasons behind these differences are speculative, but secular changes in the severity and mechanisms of falling could partly explain the phenomenon.

We do not know precisely whether the increase in fall-induced TBI is related to an increase in falls or to an increase in TBI after a fall. Nowadays, older adults, or at least the frailest among them, may fall more seriously than their predecessors. This could result in increase in these severe injuries. Changes in living arrangements, impaired balance and vision, and sensory neuropathy might have contributed to this. Today's older people live longer because of more effective health care and life-extending treatments and medication, and have many chronic disorders (Kannus et al. 1999). Some strong external risk factors for falling, such as polypharmacy, may have become more common among older adults (Tinetti and Kumar 2010). Moreover, concerning cervical spine injuries increasing degenerative changes (with diminished flexion-extension mobility and spinal stenosis) and osteoporosis in the cervical spine of older adults could contribute to the increased risk for spinal injury after a relatively minor trauma (Hagen et al. 2005).

One explanation for the above noted difference could be that changes in the biomechanics of falling could cause more head impacts. A recent video study on authentic falls of older adults in long-term care facilities showed that head impact occurred in surprisingly many cases (37 %) and that head impact was particularly common in forward falls (Schonnop et al. 2013). Most commonly the head struck the ground and in 16% of cases the furniture (Schonnop et al. 2013). It has been reported that fatal ground level falls involving skull or neck fractures most likely result in impact forces that are relatively perpendicular to the spine and torso; in other words, the head-torso orientation is roughly parallel with the ground at the time of head impact (Freeman et al. 2014). On the other hand, in fatal cervical spine injuries the major force was usually backward motion of the head accompanied by a compressive downward motion, and abrasions on the face or forehead were typical indicators of a fall (Osawa et al. 2008).

Many of the elderly male victims of fatal cervical spine injury have displayed elevated blood alcohol levels (Osawa et al. 2008). Alcohol drinking has been recognized a preventable risk factor for TBI (Current Care Guideline 2008; Puljula et al. 2013). As many as half of all TBI patients are under the influence of alcohol at the time of injury and alcohol also affects poorly to the outcome of the injury (Vaaramo 2013). Thus, increased alcohol consumption could partly explain the observed rise in fall-induced injuries to the head and cervical spine among older adults. However, in Texas, USA only 3% of older adults with acute cervical spine fracture had positive blood alcohol levels compared with 53% in younger patients (Wang et al. 2013).

Another potential explanation for the rise in fall-induced TBI is that changes in the use of medications have influenced the type and anatomic site of fall-induced head injuries. It has been reported that the type of TBI has changed with subdural and subaracnoid hemorrhages increasing, and that the use of anticoagulant and antiplatelet agents has been suggested to be the reason for this change (Harvey and Close 2012). Oral anticoagulation increases the risk for mortality among older patients who fall (Inui et al. 2014). Especially the INR (International Normalized Ratio) value over 4.0 (a measure of anticoagulant effect) and age over 70 years are associated with higher mortality in patients with head injury (Mak et al. 2012). The number of Finnish people with anticoagulation and warfarin treatment has increased in the new millennium (Lassila et al. 2009). The use becomes more frequent with age and is more common among men: around one fifth of Finnish men aged 85 years or older is on warfarin compared to around 16% among women (Lassila et al. 2009).

One possible reason for the increasing incidence of head region injuries among older adults could simply be advances in the diagnostics of TBI and cervical spine injury with computed tomography (CT) scanning and magnetic resonance imaging (MRI) coming more available. It has been reported that patients aged 65 years or older were three times more likely to receive a head CT or MRI compared to younger patients presenting with TBI (Pearson et al. 2012). Australian authors suggested that their observation of increasing number of severe fall-induced head injuries could partly be explained by routine CT scanning being mandated at the very end of their study period (Watson and Mitchell 2011). They also suggested that if improvements in diagnostics were the explanation, a stabilization of these injuries should occur in the future (Watson and Mitchell 2011). However, better case ascertainment and reporting hardly explain the results of our nationwide register study since the definition of TBI remained the same over the study period.

We included all patients hospitalized for these severe injuries and the decision for hospital admission of a patient has always been based on the general condition of the patient rather than advances in imaging technology. In addition, no major changes have been made to general guidelines on diagnosis and treatment of these injuries in Finland to our knowledge. This is confirmed further by the fact that in 1970-2012 rather stable or even declining incidence of fall-induced cervical spine injuries was observed in the younger reference group (patients aged 20-49 years).

In the current study, the rate for fall-induced cervical spine injuries and fall deaths was higher in men than women, while the reverse was true for hip fractures and fall-induced injuries overall. The rate for TBI was quite equal between genders. A detailed analysis of TBI in Australia revealed that men had serious head injuries more often than women (Jamieson and Roberts-Thomson 2007). Since the general incidence of falling is higher in elderly women than elderly men, it can be hypothesized that elderly men have a greater risk for severe outcomes of falls than their female counterparts. Taller and heavier body (and thus higher impact energy while falling), higher consumption of alcohol, poorer nutritional status, greater occurrence of comorbidities and greater risk-taking behavior among older men compared to older women may explain this gender disparity. Further studies are, however, needed to confirm our observations and elaborate the reasons for the difference between genders.

6.4 Prospects for the future and implications for future studies

If the observed trends in this study continue, the number of fall-induced injuries of older adults will substantially increase during the coming decades. This is even the case with the declining incidence of fall-induced injuries because our older population at risk is expanding rapidly in the near future. The problem is especially alarming in TBIs and cervical spine injuries since the incidence of these injuries increased during the entire study period without signs of levelling off. The only exception might be hip fractures: if the declining fracture incidence continues, the annual number of these injuries might even slightly decrease in the coming decades.

Thus, it is the combination of high injury incidence and sharply increasing population at risk that makes the fall injury problem so severe in our older population. The only way to limit the number of these injuries is to decline its incidence further by effectively preventing falls and subsequent injuries.

In addition to the increasing numerical burden of these injuries, treatment of the patients may become more demanding in the future. First, the average age of the patients with a fall-induced injury increased between 1970 and 2012. Older adults with TBI have been reported to have more in-hospital procedures (such as imaging and surgery) and more likely to require continued medical care than their younger counterparts (Dams-O'Connor et al. 2013). Second, the increasing number of multiple pre-existing medical comorbidities and polypharmacy among older adults makes TBI and other fall injuries more difficult to diagnose and treat. This is likely to increase the risk for secondary complications (Dams-O'Connor et al. 2013). It has also been suggested that the current tendency to support older people to remain in their own homes longer could result in exposing them to a greater risk of sustaining a fall-related injury (Watson and Mitchell 2011).

Many of fall injuries could be prevented. The US Public Health Service has estimated that two-thirds of deaths due to falls are potentially preventable (Rubenstein 2006). It has also been estimated that one third of hip fractures could be prevented with exercise (Sievänen et al. 2014). As we now have evidence-based information about effective fall prevention programs, they need larger implementation (Karinkanta et al. 2010). The challenge is how to assure the full and effective use of the programs in practice (Fixsen et al. 2011). In Finland, a recent publication of The Ministry of Social Affairs and Health stated that the national target is to reduce the number of severe and fatal home and leisure accidents by 25% by the year 2025 (The Ministry of Social Affairs and Health 2013). It was stated further that the need and possibilities for national-level TBI prevention will be clarified (The Ministry of Social Affairs and Health 2013).

Related to this, a recent video analysis of head impacts during authentic falls of older persons suggested that backward rotation of the body during the descent phase of the fall could protect the head, but hand impact as protective response appeared ineffective (Schonnop et al. 2013). Thus, improving upper-limb strength and teaching falling techniques were suggested to reduce fall-related head impacts in older adults (Schonnop et al. 2013). Since there is a gender difference in the profile of fall-induced injuries, a question has been raised if strategies for injury prevention are more difficult to implement to men than women (Jamieson and Roberts-Thomson 2007).

Recurring falls and secondary hip fractures are common in the elderly population (Lönroos et al. 2007). Because the causes and risk factors of the index fall remain too often uninvestigated, the patient is likely to stay at high risk for future falls and injuries. This calls for effective implementation of the secondary

strategies of fall prevention in Finland and elsewhere (Salter et al. 2006; Salonoja et al. 2010).

Further studies are needed to confirm the observations of this thesis and elaborate the reasons for the changes in the profile of fall-induced injuries and differences between genders in fall-induced deaths. Complementary detailed investigation of deaths certificates would be of interest. This would reveal more information on the circumstances of fall-induced deaths, and the specific injury types and details of the fatal falls. The gender differences in the specific injuries the deceased received in the fall accident would be valuable information.

For now, the Finnish OCDS are very reliable, but challenge in the future is to maintain the high medical and medico-legal autopsy rates and thus the quality in detecting the causes of death. Autopsies are of great importance since there is a 10% probability that medical autopsy will change the perception of the cause of death among hospitalized patients (Lindsberg and Karjalainen-Lindsberg 2003). Autopsies are also important for educational purposes.

The alarming rise in TBI of older adults is worthy of further research: a more detailed analysis of hospitalized patients, diagnoses confirmed with CT or MRI imaging, and sub-mechanisms of falls would be of interest. More detailed information on patient characteristics (such as comorbidities, medications, alcohol consumption, living arrangements, length of hospitalization, and treatment) might suggest reasons for the increase in incidence. In addition, it would be useful to identify the mechanisms and risk factors of fall-induced cervical spine injuries of our elderly adults and have more precise information on the treatment practices and outcomes of these injuries.

7 CONCLUSIONS

The main findings of this thesis can be summarized as follows:

1. Falls are the leading cause of unintentional injury deaths in Finland and the number of fall-induced deaths of older adults increased considerably during the study period from 1970 to 2012. Currently men have higher annual number and age-adjusted incidence (that is, the average individual risk) of fall-induced deaths compared with women.
2. After continuous increase from early 1970s to late 1990s, the age-adjusted incidence of fall-induced injuries and hip fractures started to decrease and the decrease has continued to present day.
3. In contrast, the age-adjusted incidence of fall-induced TBIs and cervical spine injuries of older adults has increased for the entire study period indicating that the profile of fall-induced injuries has changed during the new millennium.
4. The overall number of fall-induced injuries and deaths among older Finns will increase in the future - even in a case that the injury incidence continues to decline with the current rate. This will be a great challenge for Finnish health care and entire society.

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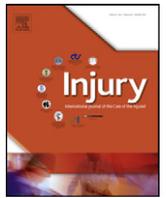
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ORIGINAL PUBLICATIONS



Unintentional injury deaths among adult Finns in 1971–2008

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ABSTRACT

Injuries are a significant public health problem and among the leading causes of death worldwide. In Finland, nearly 1.2 million accidents or assaults lead to physical injury annually. This study examined the nationwide trends in unintentional injury deaths of adults in Finland. For this purpose, we obtained from the Finnish Official Cause-of-Death Statistics (OCDS) the data for persons aged 15 years or older whose deaths occurred in 1971–2008 due to an unintentional injury.

A drastic decline occurred in road traffic crashes. The age-standardized death rate (per 100 000 person-years) of men's road traffic crashes was 48 in 1971 but only 10 in 2008. Traffic caused fewer deaths in women than men, but the declining trend in women's death rates was also clear, from 17 in 1971 to 3 in 2008. During the study period, falls became the leading category of men's unintentional injury death, although their rate rose rather slowly from 19 in 1971 to 21 in 2008. Among Finnish women, the rate of fall-induced deaths declined from 32 in 1971 to 16 in 2008.

There was a notable rise in men's unintentional alcohol poisoning deaths, especially since 2003. In 2008, alcohol poisonings were the second leading cause of men's injury death (rate 18). The rate of women's deaths due to alcohol poisoning was yet low during the entire study period but its rise was clear, from 1 in 1971 to 5 in 2008. Poisoning deaths caused by other substances also increased: among men their rate was 4 in 1971 and 11 in 2008, and among women 2 in 1971 to 4 in 2008. Between 1998 and 2008, psychotropic drugs, narcotics and opioid analgesics caused the majority of both men's and women's non-alcohol poisoning deaths.

In conclusion, unintentional injury deaths in road traffic crashes declined steeply among adult Finns during 1971–2008. The rate of fall-induced deaths in Finnish men was rather stable during the study period while in women it clearly declined. In contrast, increase in poisoning deaths due to alcohol and other substances was alarming. Vigorous preventive actions should be initiated to control this development.

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Introduction

Injuries are a significant public health problem, a common cause of disability and years of life lost and a major contributor to health care costs.^{7,10,12,21,22} In Finland, nearly 1.2 million accidents or assaults lead to physical injury annually. Unintentional injury is the leading cause-of-death for persons aged 15–44 years and the fourth leading cause-of-death among all age groups combined in Finland.¹⁵ Although the general injury-related mortality reduced in the 20th century,^{8,21,22} the death rates have increased since 1990s.^{1,6,8,17}

Previously we reported the secular trends in unintentional injury deaths among adult Finns and concluded that the observed rise in

men's fall-induced deaths and women's deaths due to alcohol poisoning needed close follow-up.¹² In that work, we suggested systematic fall prevention measures to control the increase in fall-induced deaths in modern aging societies. Soon afterwards, Finnish alcohol policy became more liberal and it was of interest to see how this contributed to the profile of unintentional injury deaths. We have now followed the nationwide database for 38 years (to the end of 2008) to assess the current secular trends in unintentional injury mortality rates among persons 15 years of age or older in Finland, an EU-member country with a well-defined Caucasian population of 5.3 million people.

Materials and methods

We obtained from the Finnish Official Cause-of-Death Statistics (OCDS) the data for persons aged 15 years or older who died because of an unintentional injury between 1971 and 2008. This

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statutory register has been computer-based since 1971, and since its inception, it has been updated and reviewed for data quality by the Cause-of-Death Bureau at Statistics Finland.¹⁵ The Finnish OCDS contain data on age, sex, marital status, place of residence, and place, cause and time of death of the deceased. The main categories of death from unintentional injury are road traffic crashes, water traffic crashes, falls, drownings, alcohol poisonings and other poisonings. For deaths from intentional injury, the main categories are suicides and homicides.

In practice, the Finnish OCDS are 100% complete, since each death, its official certificate (issued by the physician who certified the death), and the corresponding biographical data in our computerized population register are cross-checked.¹⁵ The accuracy of the data is, in turn, maximized by three independent examinations of the codes of the death certificate.^{10,15} In injury-based deaths, the accuracy of the Finnish death certificates and their cause-of-death codes are verified further by autopsies performed in 94–97% of these deaths.^{10,15}

The mortality data were drawn from the entire 15-year-old or older population of Finland, which was 3 504 845 in 1971 and 4 420 523 in 2008.¹⁶ Thus, the below given absolute numbers and incidences of deaths were not cohort-based estimates but true descriptions of the population. In calculating the age-standardized death rates (per 100 000 person-years), the age adjustment was performed separately for men and women by means of direct standardization using the mean 15-year-old or older population between 1971 and 2008 as the standard population.

We examined more closely the category of non-alcohol poisoning deaths because they have been said to be an increasing problem.^{7,18,20,25} These deaths were defined as those having underlying cause-of-death codes X40–44 (including drugs) and X46–49 (including other substances) in the International Classification of Diseases, Tenth Revision (ICD-10). This detailed data was available from 1998 onwards and included poisoning deaths due to overdoses of illegal and legal drugs (taken for nonmedical reasons), and poisoning deaths due to legal drugs taken in error or at wrong dose. For the other categories, the underlying cause-of-death codes in the ICD-10 were V01–V79 for road traffic crashes, V90–V94 for water traffic crashes, W00–W19 for falls, W65–W74 for drownings, and X45 for alcohol poisonings.

Results

Men

Among Finnish men, a drastic decline in both the number and age-standardized rate of injury deaths between 1971 and 2008 occurred in road traffic crashes (Fig. 1A and B and Table 1). The age-standardized death rate (per 100 000 person-years) of men's road traffic crashes was 48 in 1971 but only 10 in 2008. On the contrary, the number of men's fall-induced deaths steadily increased during this period, falls being the leading category of men's unintentional injury death in 2008 (Fig. 1A). On the other hand, the slowly increasing trend in men's age-standardized death rate of falls leveled off at the end of 1990s (Fig. 1B).

There was a notable rise in the number and age-standardized rate of men's unintentional alcohol poisoning deaths, especially since 2003. These deaths are now the second leading cause of men's injury death (Fig. 1A and B and Table 1). The age-standardized rate of these poisonings was 14 in 1971 and 18 in 2008.

In recent years non-alcohol poisoning deaths also surpassed road traffic crashes as a cause of men's injury death (Fig. 1A and B and Table 1). The age-standardized rate (per 100 000 person-years) of these deaths was 4 in 1971 and 11 in 2008. In this category, the group of psychotropic drugs and the group of narcotics and opioid analgesics caused the majority of men's poisoning deaths between

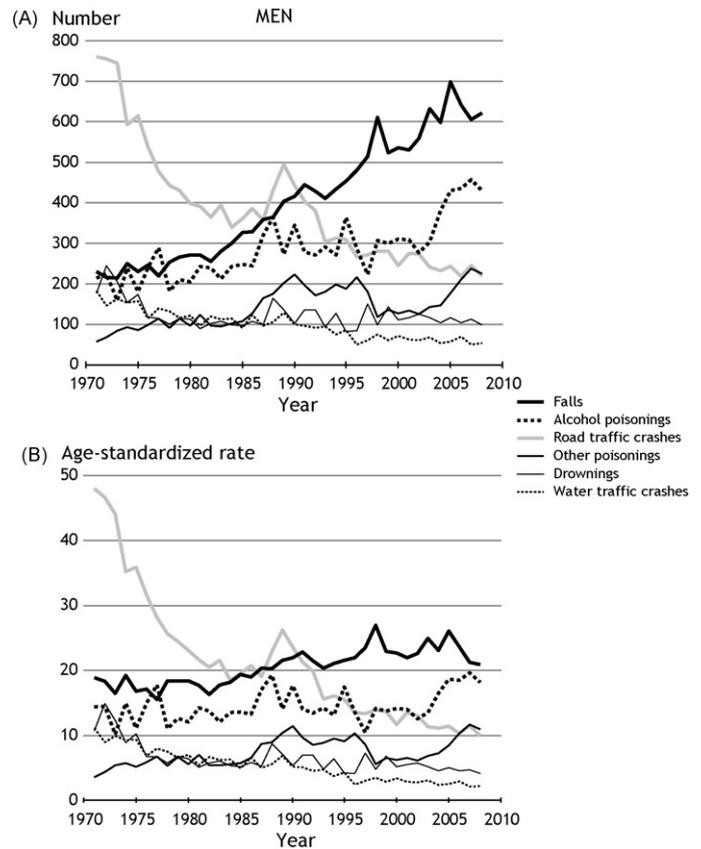


Fig. 1. Number (A) and age-standardized rate (B) of the most frequent unintentional injury deaths in Finland among men 15 years of age or older during 1971–2008.

1998 and 2008 (Fig. 2). Also, deaths due to nonopioid analgesics increased since the year 2005 (Fig. 2). Other substances (ICD-10 codes X46–49) caused only few deaths in the study period.

Women

Among Finnish women, falls were the leading cause of unintentional injury death for the entire period 1971–2008 (Fig. 3A and B and Table 1). The number of fall-induced deaths rose, but the corresponding age-standardized death rate declined, especially during the most recent years of observation. In 1971,

Table 1

The leading causes of unintentional injury deaths among adult Finns in 1971 and 2008 (age-standardized death rates per 100 000 person-years).

Men			
	1971	2008	
Road traffic crashes	48.0	Falls	20.9
Falls	18.9	Alcohol poisonings	18.2
Alcohol poisonings	14.4	Non-alcohol poisonings	11.0
Water traffic crashes	11.1	Road traffic crashes	10.0
Drownings	10.7	Drownings	4.1
Non-alcohol poisonings	3.6	Water traffic crashes	2.2
Women			
	1971	2008	
Falls	32.0	Falls	15.6
Road traffic crashes	17.2	Alcohol poisonings	4.9
Non-alcohol poisonings	2.0	Non-alcohol poisonings	4.1
Drownings	1.4	Road traffic crashes	3.3
Alcohol poisonings	0.9	Drownings	0.6
Water traffic crashes	0.6	Water traffic crashes	0.0

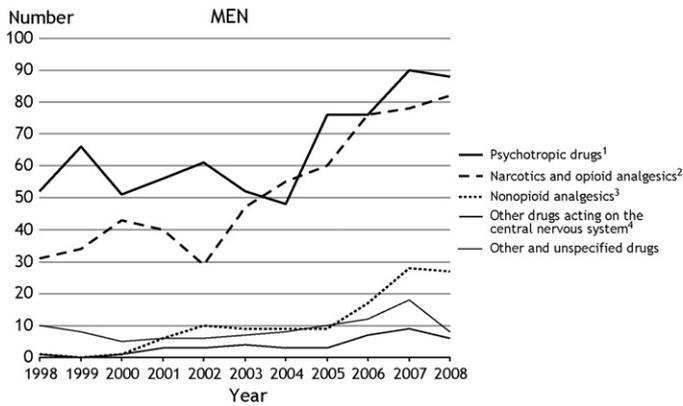


Fig. 2. Number of non-alcohol poisoning deaths in Finland among men 15 years of age or older during 1998–2008. ¹Includes antidepressant, and sedative-hypnotic, antipsychotic and antiepileptic drugs, ²includes hallucinogens, opioid analgesics and illicit drugs such as heroin and cocaine, ³includes non-steroidal anti-inflammatory drugs and other antipyretic and antirheumatic drugs (both prescription and over-the-counter drugs), ⁴includes, for example, parasympatholytic or parasympathomimetic drugs and sympathomimetic drugs.

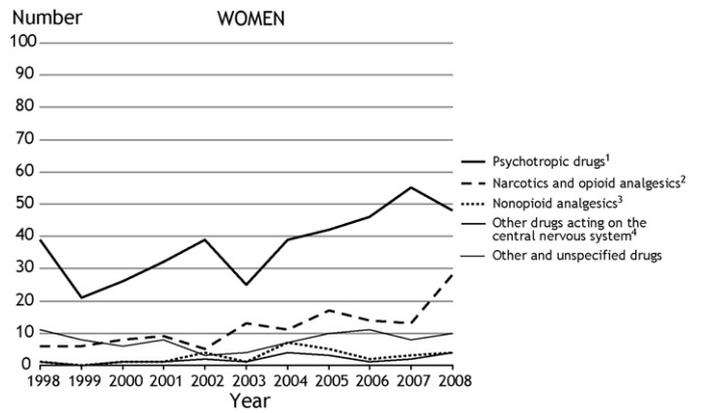


Fig. 4. Number of non-alcohol poisoning deaths in Finland among women 15 years of age or older during 1998–2008. ¹Includes antidepressant, and sedative-hypnotic, antipsychotic and antiepileptic drugs, ²includes hallucinogens, opioid analgesics and illicit drugs such as heroin and cocaine, ³includes non-steroidal anti-inflammatory drugs and other antipyretic and antirheumatic drugs (both prescription and over-the-counter drugs), ⁴includes, for example, parasympatholytic or parasympathomimetic drugs and sympathomimetic drugs.

this rate (per 100 000 person-years) was 32, while only 16 in 2008. Traffic caused fewer deaths in women than men during the entire period of 1971–2008, but the declining trend in women’s death rates was also clear, from 17 in 1971 to 3 in 2008 (Fig. 3A and B and Table 1).

The age-standardized rate of women’s deaths due to alcohol poisoning was rather low during the entire study period; however, its rise was clear, from 1 in 1971 to 5 in 2008. In 2005, alcohol poisoning surpassed road traffic crashes as a cause of women’s

injury death (Fig. 3A and B). A similar rise was observed in the rate of women’s non-alcohol poisoning deaths, from 2 in 1971 to 4 in 2008 (Fig. 3B and Table 1). In this category, psychotropic drugs caused the majority of the deaths between 1998 and 2008, although deaths due to narcotics and opioid analgesics increased most rapidly (Fig. 4).

Discussion

Finland has experienced a drastic change in the profile of unintentional injury deaths between 1971 and 2008 with falls and poisonings replacing road traffic crashes as the leading causes of injury-induced death. The decline in traffic-induced deaths has been remarkable, particularly given that the Finnish car pool and driven kilometers per year have multiplied during the recent decades. The reasons for this positive time trend are multifactorial, but the most likely explanation is improved traffic safety, perhaps the result of the multidimensional traffic safety program conducted in Finland since the late 1960s. The program has included road and traffic planning and legislation, more comprehensive traffic supervision and control (particularly controlling speeds and driving under the influence of alcohol and illicit drugs), improved vehicular safety (car body, seats, seat belts, air bags, and child safety-seat restraints), and intense promotion of the use of bicycle helmets and other traffic safety issues among the general public.¹² More rapid access to emergency services and improved trauma care is an additional factor that may relate to the above-noted decline in fatal traffic injuries.^{21,22}

Falls are the number one cause in injury-induced deaths among Finnish men and women, most of the victims being elderly persons.^{10,11} The number of fall-induced deaths is expected to increase with continuous aging of the population.¹⁶ However, the current study shows that the age-standardized rate (i.e., average individual risk) of fall-induced deaths has stabilized (men) or even declined (women) in recent years. One reason for this positive development could be that the average functional ability of the older adults has improved in Finland.^{9,24} Nevertheless, the number of older adults in Finland is rising so rapidly that there is a clear need for effective falls prevention actions to reduce the number of fall-induced injuries and related deaths. This should receive high priority in our health policy since elderly individuals’ falls prevention is effective and the measures can be organized cost-effectively.¹³

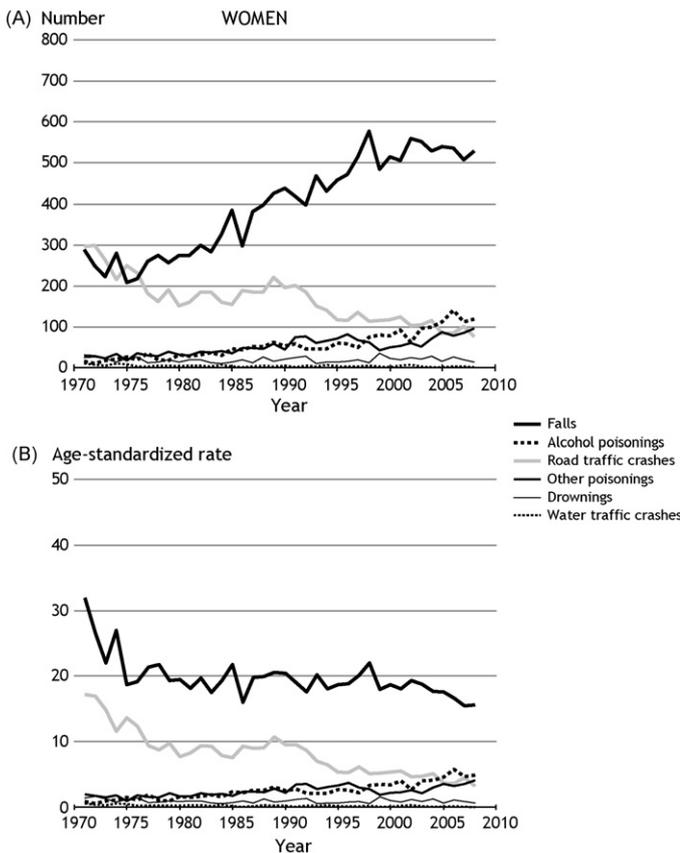


Fig. 3. Number (A) and age-standardized rate (B) of the most frequent unintentional injury deaths in Finland among women 15 years of age or older during 1971–2008.

The alarming rise in poisoning deaths due to alcohol, especially in the new millennium and among women, is probably the consequence of more liberal alcohol use, an increased general acceptance for women's alcohol use, and many liberating changes in alcohol policies in Finland. In 2004, quotas for tax-free imports of alcoholic beverages from other EU countries were abolished (this resulted in significant increase in importing alcoholic beverages to Finland) and alcohol beverages taxes were lowered by an average of 33%.²⁶ As a result, between 2000 and 2008, the documented total consumption of alcohol increased 20% in this country.²⁶

Our finding on the recent quick rise in alcohol poisoning deaths in Finland is in accordance with that reported by Herttua et al.⁵ They showed that alcohol-related overall mortality increased after the reduction in alcohol prices. Thus, it seems that our findings of increasing poisoning deaths due to alcohol are a part of a larger issue of alcohol-related mortality in Finland: for example, deaths due to alcohol cirrhosis and hepatitis have increased 116% during the last 10 years.³ All these findings indicate that our alcohol policy needs urgently rethinking, and most likely, subsequent restrictive actions. The same seems to concern many other countries.²³

Our study revealed a remarkable increase in unintentional non-alcohol poisoning deaths among adult Finns during the most recent years of observation. A similar increase has been reported in the United States at the beginning of the new millennium.^{2,6,18} Psychotropic drugs caused the majority of these deaths in Finland. This was especially the case among women.

Within the group of psychotropic drugs, the consumption of antidepressants has increased sixfold, and that of opioid analgesics, fourfold in Finland since the beginning of 1990s.¹⁴ On the other hand, in our study deaths caused by narcotics and opioid analgesics increased most rapidly, and Vuori et al. reported that opioid analgesics are the main cause behind the increasing numbers of poisoning deaths in Finland.²⁵ This suggests that some of the drug abusers have replaced illegal drugs with prescription opioid analgesics.²⁵ Similar findings have been reported in the United States^{18,20} and there seems to be a relationship between opioid analgesics sales and drug poisoning mortality.¹⁹

Opioid analgesics are fairly easy to acquire in Finland because a physician prescribing the drug has no possibility to check if the patient has received similar prescriptions from other clinicians. Also, their acquisition from abroad has grown during recent decades. It has been reported that among unintentional pharmaceutical overdose fatalities doctor shopping occurred in over 20% of cases and, on the other hand, among decedents who had taken opioid analgesics, less than half had ever been prescribed these drugs.⁴ Although pain management has improved in the recent years there seems to be an urgent need to counsel patients about the risks of overdosing and prevent illicit drug delivery.

In conclusion, unintentional injury deaths in road traffic crashes declined steeply among adult Finns during 1971–2008. The age-standardized rate of fall-induced deaths in Finnish men was rather stable during the study period while in Finnish women it clearly declined. In contrast, increase in poisoning deaths due to alcohol and other substances was alarming. Vigorous preventive actions should be initiated to control this development.

Conflict of interest statement

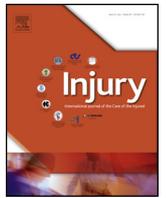
The authors have no conflicts of interests to declare.

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Fall-induced deaths among older adults: nationwide statistics in Finland between 1971 and 2009 and prediction for the future



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ABSTRACT

Background: Fall-related injuries and deaths of elderly people are a major public health concern.

Methods: Using the Official Cause-of-Death Statistics of Finland we determined the current trends in the number and age-adjusted incidence (per 100,000 persons) of fall-induced deaths among older Finnish men and women by taking into account all persons 50 years of age or older who died because of a fall-induced injury between 1971 and 2009.

Results: Among elderly Finnish men, the number of deaths due to falls increased considerably between the years 1971 and 2009, from 162 to 627 (a 287% increase). The age-adjusted incidence also increased from 43.4 (per 100,000 persons) in 1971 to 57.9 in 2000, but stabilized thereafter (57.3 in 2009). Among elderly Finnish women, the number of fall-induced deaths increased till the beginning of the new millennium (from 279 in 1971 to 499 in 2000) but stabilized thereafter (506 in 2009), and, in sharp contrast to men, women's age-adjusted incidence of fall-induced deaths declined during the entire study period, the incidence being 77.2 in 1971 while only 35.3 in 2009.

Conclusions: Between 1971 and 2009 the number of fall-induced deaths increased among elderly Finns. The changes were sex-specific so that men surpassed women in both the number and age-adjusted incidence of these fatal falls. Welcome observations were that men's age-adjusted incidence of fall-induced deaths started to stabilize during the new millennium and that in women this incidence continuously declined between 1971 and 2009.

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Introduction

Falls and fall-related injuries among elderly people are a major public health concern causing significant morbidity and mortality.^{1,2} In Finland, unintentional injury is the sixth leading cause of death for adults 65 years of age and older, and falls are the number one cause of injury-induced deaths.^{3,4}

To the best of our knowledge, many countries have so far reported increasing rates of fall-induced deaths among older adults.^{5–8} Changes by time and between the sexes have been somewhat inconstant⁹ but most recent studies seem to suggest that during the new millennium the rates of fall-induced deaths have been increasing and especially that the absolute number of these deaths is increasing rapidly.^{9,10}

In Finland, as in many other developed countries, ageing population is creating continuously increasing demands on the health care system. Previously we reported nationwide trends in fall-induced deaths of older Finns and observed that the problem was steeply rising, especially among older men.¹¹ We have now followed our nationwide fall death statistics from 1971 to 2009 to assess most recent changes. Our aim was to better understand the current fall problem in our older men and women and determine the need for falls prevention.

Materials and methods

We obtained the data for adults aged 50 years or older who died because of a fall-induced injury between 1971 and 2009 from the Finnish Official Cause-of-Death Statistics. This statutory register has been computer-based since 1971, and since its inception, it has been updated and reviewed for data quality by the Cause-of-Death Bureau at Statistics Finland.² The main categories of death from unintentional injury are road traffic crashes, water traffic crashes,

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falls, drownings, alcohol poisonings and other poisonings. In intentional injury deaths, the main categories are suicides and homicides.³

In practice, the Finnish Official Cause-of-Death Statistics are 100% complete, since each death, its official certificate (issued by the physician who certified the death), and the corresponding person information in our computerized population register are cross-checked.³ The accuracy of the data is, in turn, maximized by three independent examinations of the codes of the death certificate.^{2,3} In injury-based deaths, the accuracy of the Finnish death certificates and their cause-of-death codes are verified further by autopsies performed in 94–97% of these deaths.^{2,3}

The mortality data were drawn from the entire 50-year-old or older population of Finland, which was 1,154,968 in 1971 and 2,058,770 in 2009.¹² Thus, the absolute numbers and incidences of deaths were not cohort-based estimates but true descriptions of the whole population, and therefore, in full agreement with our previous studies,^{2,11} 95% confidence intervals were not calculated. In calculating the age-adjusted incidences of fall-induced deaths (per 100,000 person-years), the age adjustment was done separately for men and women by means of direct standardization using the mean population of persons aged 50 years or older between 1971 and 2009 as the standard population. The age-specific incidence rates were calculated for the age groups of 50–59, 60–69, 70–79 and 80 years and older.

A linear regression model was used to predict the age-specific incidence rates of fatal falls until the year 2030, and then, within each age and sex group, the predicted absolute number of these deaths was obtained by multiplying the incidence by the estimated population, the latter being obtained from the Finnish Population Projects 2010–2030.¹³

Results

Men

Among older Finnish men, the number of deaths due to falls increased considerably between the years 1971 and 2009: from 162 to 627 (a 287% increase) (Fig. 1). Since 2003, the annual number of fall-induced deaths was higher in men than women. The age-adjusted incidence also increased from 43.4 (per 100,000

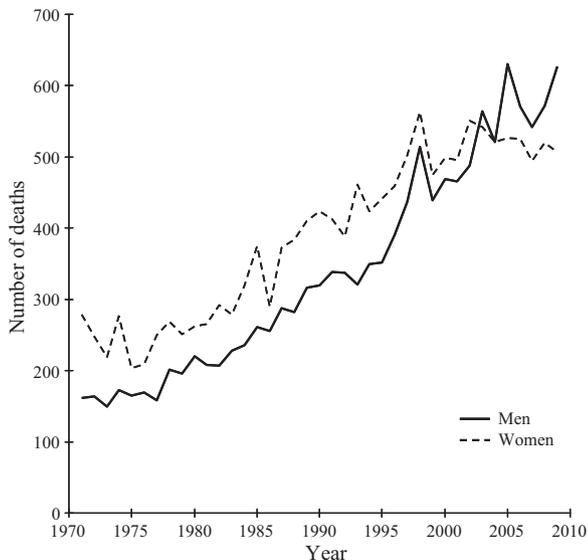


Fig. 1. The number of fall-induced deaths among Finnish men and women aged 50 years or older in 1971–2009.

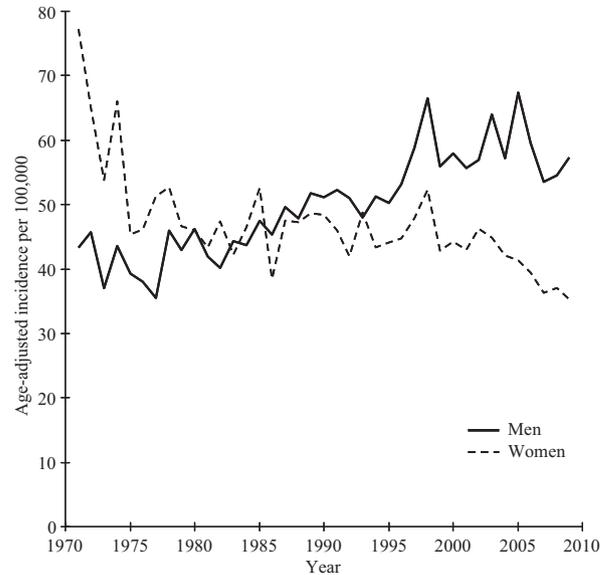


Fig. 2. Age-adjusted incidence (per 100,000 persons) of fall-induced deaths in Finnish men and women aged 50 years or older in 1971–2009.

persons) in 1971 to 57.9 in 2000, but stabilized thereafter (57.3 in 2009) (Fig. 2). Since 1986, this incidence has constantly been higher in men than women.

In 1971–2009, the majority of men's fall-induced deaths occurred in the oldest age group (80 years or older) and the incidence growth was deepest in this group (Fig. 3A). An increase also occurred in the younger age groups of men (Fig. 3A).

If the age-adjusted incidence of men's fall-induced deaths continues to rise at the average rate observed between 1971 and 2009 and the size of the 50 year old or older male population of Finland increases as predicted (from 944 221 in 2009 to 1 180 889 in 2030), the number of these deaths among men will be 2.5-fold higher in 2030 (1556 deaths) than in 2009 (627 deaths) (Fig. 4). The rapid increase is likely to be due to the increased number of deaths in the oldest age-group (80 years or older), although according to this prediction the number of fall-induced deaths will also increase in the younger age groups of men (Fig. 5A).

Women

Among older Finnish women, the number of fall-induced deaths increased till the beginning of the new millennium (from 279 in 1971 to 499 in 2000) but stabilized thereafter (506 in 2009) (Fig. 1). In sharp contrast to men, women's age-adjusted incidence of fall-induced deaths declined during the entire study period, the incidence being 77.2 in 1971 while only 35.3 in 2009 (Fig. 2). Between 1971 and 2009, the majority of fall-induced deaths occurred in women 80 years old or older and clearly fewer deaths occurred in younger women (Fig. 3B). The incidence decline was deepest in the oldest age group (Fig. 3B), although a similarly declining trend was also seen in the younger age groups of women (Fig. 3B).

Assuming that the age-adjusted incidence of fall-induced deaths of women continues to decline at the average rate observed between 1971 and 2009, and that the size of the 50 year old or older female population of Finland increases as predicted, (from 1,114,549 in 2009 to 1,340,758 in 2030), the number of these deaths among women will be 1.7-fold higher in 2030 (883 deaths) than in 2009 (506 deaths) (Fig. 4). This rise will be due to the rise in the number of fall deaths among women aged 80 years or older while among younger women the number of fall deaths are likely remain at the current level (Fig. 5B).

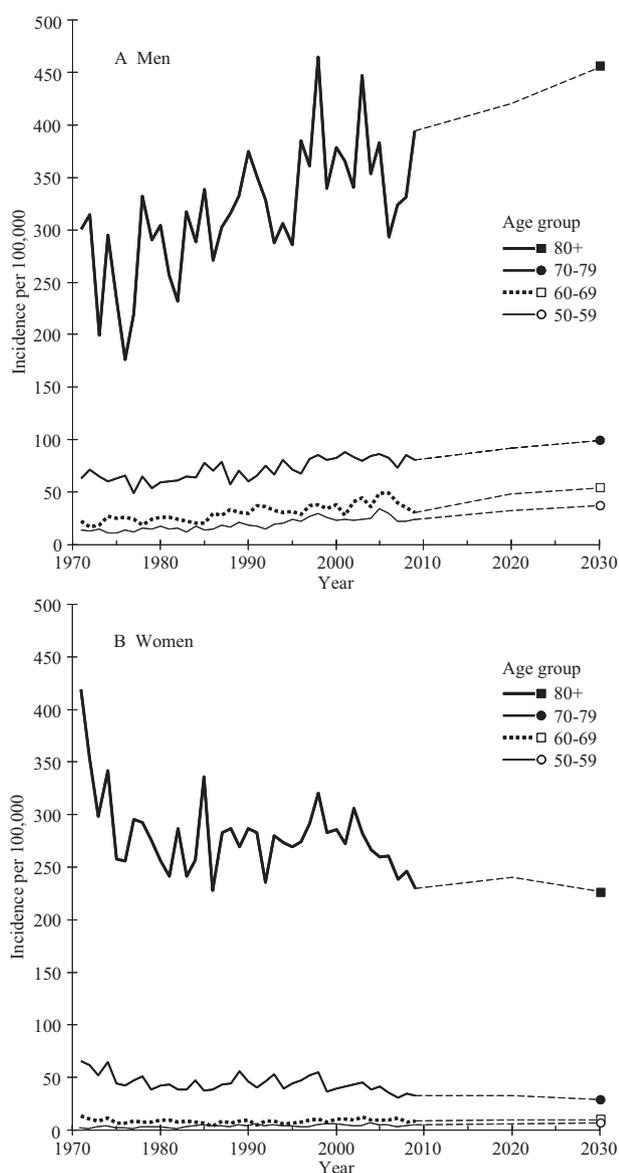


Fig. 3. (A and B) Age-specific incidences (per 100,000) of fall-induced deaths in Finland in age groups 50–59, 60–69, 70–79 and 80 years of age or older among men (A) and women (B) in 1970–2009 and prediction of the development until the year 2030.

Discussion

The current study shows that the number of fall-induced deaths of Finns aged 50 years or older increased considerably between 1971 and 2009, especially among men. During the most recent years of observation both the number and age-adjusted incidence (that is, the average individual risk) of fall-induced deaths have been higher in men than women. In men, the age-adjusted fall mortality incidence rose till the end of 1990s but levelled off thereafter. On the other hand, women's age-adjusted incidence of fall mortality clearly declined between 1971 and 2009 indicating that a major gender difference in fatal falls has developed during the recent decades.

The predicted ageing of our population is likely to emphasize the fall burden so that by the year 2030 the number of fall-induced deaths may more than double among older Finns. According to population projects and the results of this study the gender difference in the number of these deaths is likely to accentuate in the future for at least two reasons. Firstly, in men the age-adjusted

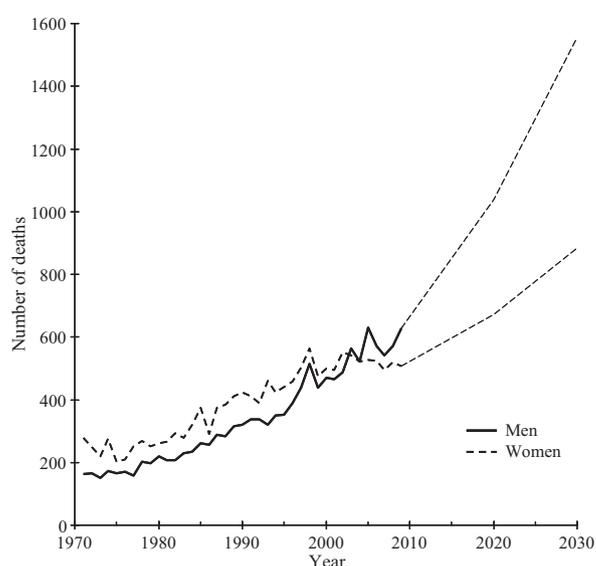


Fig. 4. The number of fall-induced deaths among Finnish men and women aged 50 years or older in 1971–2009 and prediction of the development until the year 2030. In both genders, the prediction has been made assuming that the age-adjusted incidence of fall-induced deaths continues to change at the average rate observed during 1971–2009.

incidence of falls mortality has not decreased while in women the incidence has declined continuously. Secondly, the number of older men in our population is expected to increase more rapidly than that of women. At the beginning of the study period the female/male ratio in the Finnish population aged 50 years or older was 1.42, in 2009 this ratio was 1.18, and in 2030 the predicted ratio is 1.14.

A limitation in our and other studies of fall mortality of older adults is the probable underreporting of injury deaths.¹⁴ A patient may die of late complications of an injury and so the attending physician may not be fully aware of the original injury which resulted in the chain of morbid events and finally death. On the other hand, in Finland the cause-of-death statistics have excellent coverage and high accuracy and in almost every case an injury death is verified by an autopsy.^{2,3} In addition, the death classification and its coding system have remained unchanged in Finland since 1971 thus allowing reliable database for observing changes in secular trends.

To the best of our knowledge, other countries have so far reported increasing rates of fall-induced deaths among older adults.^{5–8} Therefore, the declining incidence among older Finnish women seems unique and most welcome. In women, the fall mortality data are in accordance with our previous observations on the decreasing rate of various hospital-treated fall injuries.^{15,16} In older men, in turn, the secular trends in the rates of fall-induced injuries and deaths are less promising, although it seems that during the most recent years of observation the increasing rates have started to level off.^{15,16}

The exact reasons for the disparity between men and women in fall-induced deaths are largely unknown. One explanation could be that there is a gender difference in the mechanisms of elderly people's fall-induced deaths. Complications of a hip fracture may account for up to 50% of these deaths and secular trends in men's hip fracture rate have been less favourable than those in women.^{16,17} Men have at least twice the risk of death following a hip fracture compared to women.^{18,19} The reasons for this are still poorly understood but excess mortality among men remains even when controlled for age, fracture site, medication and chronic comorbidities.²⁰ Although most of the deaths occur within the first months after an injury,²¹ the excess annual mortality after hip

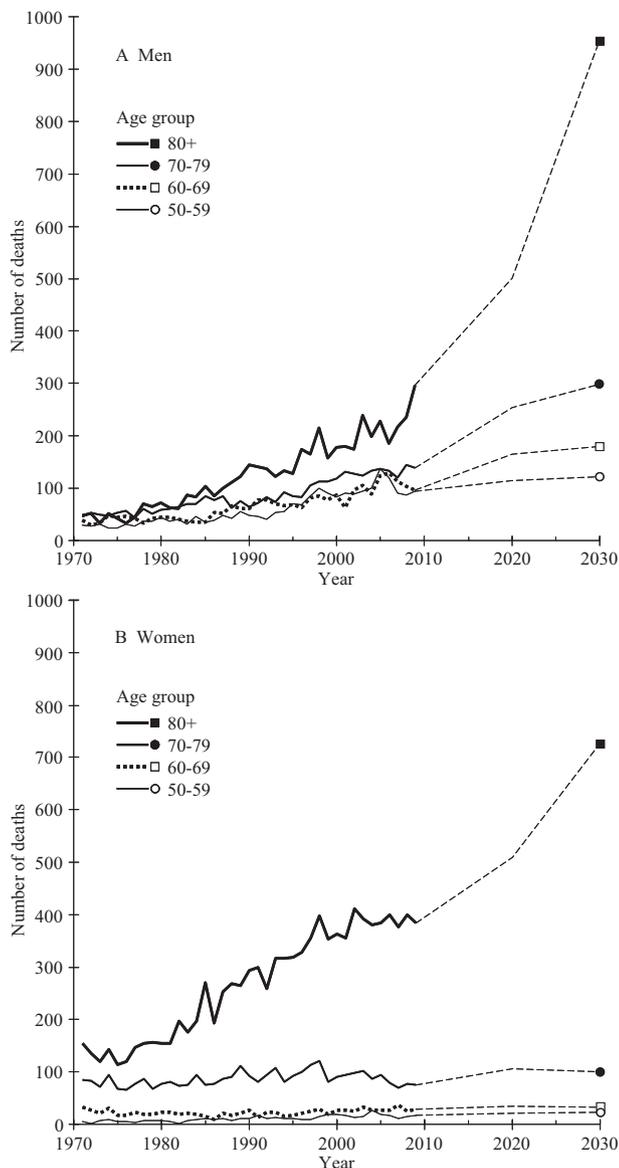


Fig. 5. (A and B) The number of fall-induced deaths in age groups 50–59, 60–69, 70–79 and 80 years of age or older in 1970–2009 and prediction of the development until the year 2030. In both genders, the prediction has been made assuming that the age-specific incidences of fall-induced deaths continue to change at the average rate observed during 1971–2009.

fracture persist over time and is at any given time higher in men than women.²² Suggestions have been made that postoperative complications following a hip fracture, such as infection, may contribute to the male excess mortality and that some comorbid conditions might be undertreated after the fracture causing more fatal acute postoperative complications among men.^{18,20,22}

Head injuries, such as subdural haematoma, also account for many fall-induced deaths of elderly people. According to some reports these injuries cover even half of all cases, especially among male population.^{17,23–25} Alcohol consumption can be related to these injuries since for example in Germany over half of men who die because of a ground-level fall have been reported of being under the influence of alcohol.²⁶ Alcohol drinking history is associated with a significantly increased risk of a fatal fall²⁷ and the total consumption of alcohol among Finnish men is increasing.^{4,28} In addition, men are more likely to engage in risky behaviours which could partly increase the risk for injurious falls.

Finally, several factors prior the fall-injury may also affect the injury outcome, such as poor mobility, impaired cognition, poor nutritional status, and low levels of physical activity. It has been reported that patients have significant long-term excess mortality after trauma especially if the injury is sustained from a fall.²⁹ Thus, falling as the injury mechanism can be an indicator of general health decline and higher mortality risk of the patient. Related to this, the current gender difference in the risk for fall-induced death could be partly explained by the improved functional ability among Finnish women compared to men since 1980s, though gender differences in improvements have been rather small.³⁰

Taken together, the present study showed that between 1971 and 2009 the number of fall-induced deaths increased among older Finns. However, the changes were sex-specific so that men surpassed women in both the number and age-adjusted incidence of these fatal falls. Welcome observations were that men's age-adjusted incidence (ie, average individual risk) of fall-induced deaths started to stabilize during the first decade of the new millennium and that in women this incidence continuously declined between 1971 and 2009. Despite this we have to effectively continue fall prevention work, since our elderly population will grow very rapidly in the near future. Elderly individuals' fall prevention programmes have been shown to be effective and the preventive measures can be organized cost-effectively,³¹ but the programmes need larger implementation. Evidence-based falls prevention consists of strength and balance training, calcium and vitamin D supplementation, and reduction in psychotropic medication.³¹ In addition, correction of visual impairment, modification of environmental hazards, and use of hip protectors and gait-stabilizing shoe devices may turn out to be effective options.

Author contributions

All authors contributed to the study design, analysis and interpretation of data and the preparation of the manuscript.

Role of the funding source

This study was funded by the Competitive Research Funding of the Pirkanmaa Hospital District, Tampere, Finland. This organization had no involvement in the study design; collection, analysis and interpretation of data; writing of the manuscript; and decision to submit the manuscript for publication.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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Declining age-adjusted incidence of fall-induced injuries among elderly Finns

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Abstract

Background Elderly people's fall-induced injuries are a major public health challenge.

Methods We determined the current trends in the number and age-adjusted incidence (per 100 000 persons) of fall-induced injuries among older adults in Finland by taking into account all persons 80 years of age or older who were admitted to Finnish hospitals for primary treatment of a first fall injury over the period 1970-2009.

Results The number of fall-induced injuries in elderly Finns increased considerably during the study period: for women and men separately, these numbers were from 927 to 10 333 (an 11-fold rise), and from 212 to 3 258 (a 15-fold rise), respectively. In both genders, the age-adjusted incidence (per 100 000 persons) of fall-induced injuries increased till the late 1990s but decreased thereafter, the incidence being 2729 (women) and 1455 (men) in 1970, and 5 930 (women) and 4240 (men) in 2009. Even with the current injury incidence the number of these injuries is expected to more than double by the year 2030.

Conclusion The rise in the age-adjusted incidence of hospital-treated fall injuries of 80 year old and older Finns from the 1970s to the late 1990s has been followed by declining injury rates. Despite this we have to effectively continue implementation of fall prevention actions.

Introduction

Falls are a major cause of morbidity and mortality among the older population and thus a major public health concern in modern societies with ageing populations [1, 2, 3]. Fall-induced injuries may reduce the quality of life of the elderly people considerably because very easily they result in long-standing pain, functional impairment and disability [1, 2, 4, 5]. In addition they have a large impact on health care costs [6, 7].

Previously we reported that the number and age-adjusted incidence of fall-induced injuries rose among Finns 80 years of age or older between 1970 and 2002 [8]. We have now followed the population another 7 years (to the end of 2009) and want to bring to immediate attention some interesting news: the rise in the incidence of fall-induced injury has leveled off and the incidence has even started to decline.

Materials and methods

Finland is an EU country with a well-defined Caucasian population of 5.3 million people. The data on the fall-induced injuries were obtained from the Finnish National Hospital Discharge Register (NHDR). This statutory computer-based register is the oldest nationwide discharge register in the world (in operation since 1967). The Register is continuously updated and monitored for quality by the Department of Registers and Statistics, National Institute for Health and Welfare, Helsinki, Finland and provides reportedly reliable data for hospital-treated injuries in Finland [1, 9, 10, 11, 12]. The register has been shown to cover acute injuries in the population adequately (annual coverage of injuries is 90 % or over) and record them accurately (annual accuracy of the NHDR injury diagnoses is also 90 % or over) [1, 9, 10, 11, 12].

To calculate the incidence rates of fall-induced injuries, annual mid-year populations were taken from the Official Statistics of Finland, the statutory computer-based population register of the country [13]. The data on fall-induced injuries were drawn from the entire 80 year old and older

population of Finland, which was 50 943 in 1970 and 242 880 in 2009. Thus, the reported absolute numbers and incidence rates of injuries were not cohort-based estimates but complete population results.

Throughout the study years, a fall-induced injury was defined as an injury occurring in Finns aged 80 years and older as a consequence of a fall from a standing height of 1 m or less and resulting in hospital admission. Only the primary treatment of a first fall injury was taken into account each year over the period 1970-2009. Thus, one person was counted only once. Injuries caused by vehicular accidents and other types of high-energy trauma were excluded. Annually, approximately 70 % of the recorded injuries were bone fractures, 12 % were soft tissue bruises and contusions, 6 % head injuries other than fractures, 5 % wounds and lacerations, 3 % joint distortions and dislocations, and 4 % other injuries.

In calculating the age-adjusted incidence of fall-induced injury (per 100 000 women and men 80 years of age and older), the age adjustment was done by means of direct standardisation using the mean 80 year old or older female and male populations between 1970 and 2009 as the standard population. The age-specific incidence rates were calculated for the age groups of 80-84, 85-89 and 90 years and older. A linear regression model was used to predict these rates until the year 2030, and then, within each age and sex group, the predicted absolute number of injuries was obtained by multiplying the incidence by the estimated population, the latter being obtained from the Finnish Population Projects 2010-2030 [14].

Results

The number of fall-induced injuries among Finns aged 80 years and older increased considerably during the study period, from 1 139 in 1970 to 13 591 in 2009 overall (a 12-fold rise). Among women, the number of fall-induced injuries rose from 927 in 1970 to 10 333 in 2009 (an 11-fold rise) and among men, from 212 in 1970 to 3 258 in 2009 (a 15-fold rise). However, the age-adjusted incidence (per 100 000 persons) of fall-induced injuries decreased in both genders since the late 1990s (Fig. 1). At the beginning of our study period in 1970 the age-adjusted incidence was 2 729 per 100 000 persons in women and 1 455 in men. Among women, the rise in age-adjusted incidence was clear till the year 1997 (rate 7 079), but then started to decline, the incidence being 5 930 in 2009. Among men, the age-adjusted incidence rose till year 1998 (rate 5 467), but also declined thereafter, the incidence being 4 240 in 2009.

Findings concerning the age-specific incidences were similar: since the late 1990s incidences of fall-induced injuries have leveled off and even started to decline among both genders and all age groups, except among the oldest old of men (Fig. 2A and B). Of note, a fall-related injury is clearly a gender-related and age-related phenomenon since the injury incidences are higher in women than men and in both genders the incidence increases with age (Fig. 2A and B).

If the age-specific incidence of fall-induced injuries continues to rise at the average rate observed between 1970 and 2009 and the size of the 80 year old or older population of Finland increases as predicted (from 242 880 in 2009 to 530 442 in 2030), the number of these injuries will be 3.5-fold higher in 2030 (47 302 injuries) than in 2009 (13 591 injuries) (Fig. 3, curve A). However, should the incidence remain at the 2009 level, the number of fall-induced injuries would be 2.2-fold higher by the year 2030 (29 694 injuries) compared to the year 2009 (Fig. 3, curve B). If we assume that the incidence continues to decline at the average rate observed since the late 1990s, the absolute number of these injuries would still increase during the coming decades (1.6-fold rise resulting in 21 478 injuries in the year 2030) (Fig. 3, curve C).

Discussion

The current epidemiologic study shows that the rise in the incidence of fall-induced injuries of 80 year old and older Finns from the 1970s to the late 1990s has been followed by declining injury rates. However, the absolute number of these injuries is not decreasing because the population at hand, persons aged 80 years or older, is constantly expanding and will do so more rapidly in the near future.

Our long-term statistics on the entire spectrum of fall-induced injuries are in line with recent reports on more specific types of fall injuries in Finland (such as hip, proximal humeral and knee fractures); the rates of these severe injuries have also stabilised or started to decline [15, 16, 17]. Many other countries have also reported declining rates of hip fractures [18, 19, 20, 21, 22, 23]. Additionally, Finnish findings concerning fall-induced deaths have been similar: the age-adjusted incidence is declining, but falls are yet the number one cause in the injury-induced deaths of adults [24, 25].

To our knowledge, our current finding on declining rate of fall-induced injuries among elderly adults is unique: to date other countries have reported rising trend of these injuries [3, 26]. Hopefully other populations are able to follow the declining Finnish trend soon.

The exact reasons for the recent decrease in age-adjusted incidence of older adults' fall-induced injuries are unknown. One explanation could be that average functional ability of elderly people in Finland has improved [27, 28, 29]. Today elderly people's lifestyle could be physically more active compared to their age-mates' in earlier decades and thus improved muscle strength, balance and coordination could reduce the risk of falling [30, 31]. In addition, changes in the environment of the older adults, such as improvements in promoting safety at home and public surroundings, and more systematic use of walking aids, could have made ambulation and moving around safer and thus reduced the risk of falling.

Previously we speculated that a cohort effect towards healthier older populations might explain the positive development that was seen in specific injury types and now in fall-induced injuries in general [15, 16, 17]. Concerning the most typical fall injury of older adults or fracture, early-life risk factors for fractures (such as perinatal nutrition) may have had stronger effect on the fracture risk in the earlier than later birth cohorts. The risen average body weight and body mass index (BMI) could also explain the declining fracture incidence: in all adult age groups of Finnish population, the prevalence of obesity (BMI 30 kg/m² or over) has increased since the 1980s [32] and, a low BMI is a strong risk factor for hip fracture and high BMI is related to decreased fracture incidence in the population [33, 34].

Considering reduction in bone fractures further, we may suspect that the average bone mass and strength have increased in 1990s due to specific measures to prevent and treat osteoporosis, such as increased exercise and increased use of vitamin D, calcium and bone-specific drugs. On the other hand, over 80% of low-trauma fractures occur in people who do not have osteoporosis [35], bone mass and strength seem not to have changed since 1970s [36] and the declining fracture trend started clearly before the above noted measures were implemented in a wider scale [15, 16, 17].

Last but not least, actions and interventions to prevent falls and their severity (such as strength and balance training, periodical medical and medication review, calcium and vitamin D supplementation, correction of visual impairments, wearing of hip protectors and gait-stabilising antislip devices, and home modification with environmental safety measures) could have had a favourable effect to injury incidence [31, 37]. However, as in other explanations, direct causal evidence is lacking.

One might speculate that our current findings on declining incidence in fall-related injury hospitalisations of older adults could be due to changes in the Finnish hospitalisation policy only (i.e., stricter criteria for injury-based hospital admissions in the new millennium). We feel that this hardly can explain the phenomenon, because similarly decreasing injury incidences have been seen

in many severe fracture types, such as hip and knee fractures, and they have always resulted in hospital admission [16, 17]. In some types of injury, such as distal radius fractures, improved surgical techniques have actually resulted in rise in the absolute and relative number of victims taken into a hospital [38].

Although our study shows positive development in the incidence of fall-related injuries of older Finns, the number of these injuries will grow (even when the incidence declines at the current rate) because the population at risk is constantly expanding. In fact, our epidemiologic study underestimates the burden these injuries will cause in the future, because we took into account only the primary treatment period of each fall injury patient to minimise the “readmission and between-hospitals transfer” problems in the statistics. Therefore, this study identified only persons who were hospitalised due to a fall injury rather than revealed all hospitalisations and treatment periods contributing to our health care costs. Apparently, the entire burden of fall-induced injuries of older adults exceeds the numbers described in this study.

In conclusion, the present study shows a positive and most welcome trend change in the incidence of fall-induced injuries among elderly Finns. Nevertheless, there is a clear need for all feasible fall prevention actions to decline the injury incidence further, since the population at risk is growing very rapidly in the near future. Many recent studies have verified that elderly individuals’ falls prevention is effective and preventive measures can be organised cost-effectively [37, 39], but the existing programmes need larger implementation.

Acknowledgement

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Key points

- Incidence of fall-induced injuries in 80 year old and older Finns has started to decline since the late 1990s
- However, sharp focus on falls prevention is needed, because our elderly population will grow rapidly in the future
- Continuous decline in the incidence of fall-induced injuries will be the only way to limit the absolute number of injuries

Supplementary data

The long list of references supporting this article has meant that only the most important are listed here and are represented by bold type throughout the text. The full list of references is considered as supplementary data and is available on the journal website.

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Figures 1-3

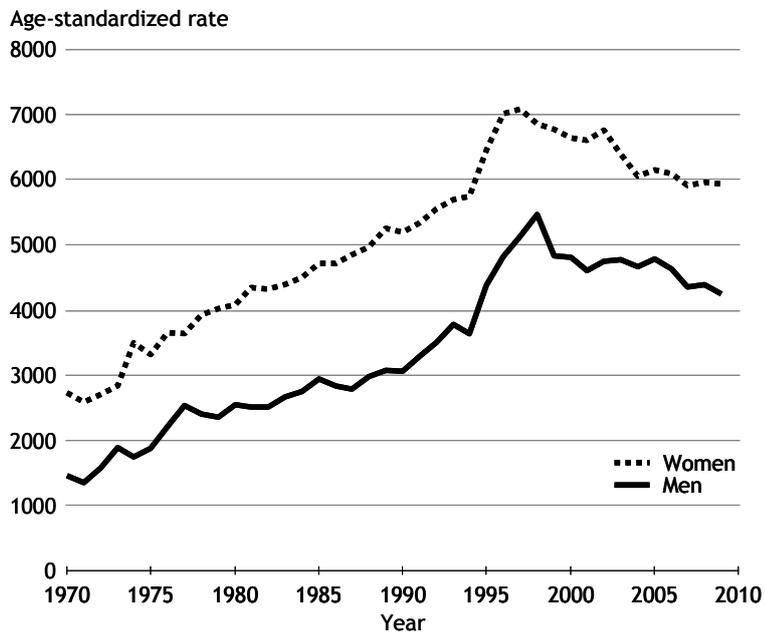


Fig 1. Age-adjusted incidence (per 100 000 persons) of fall-induced injuries in Finns aged 80 years or older in 1970-2009.

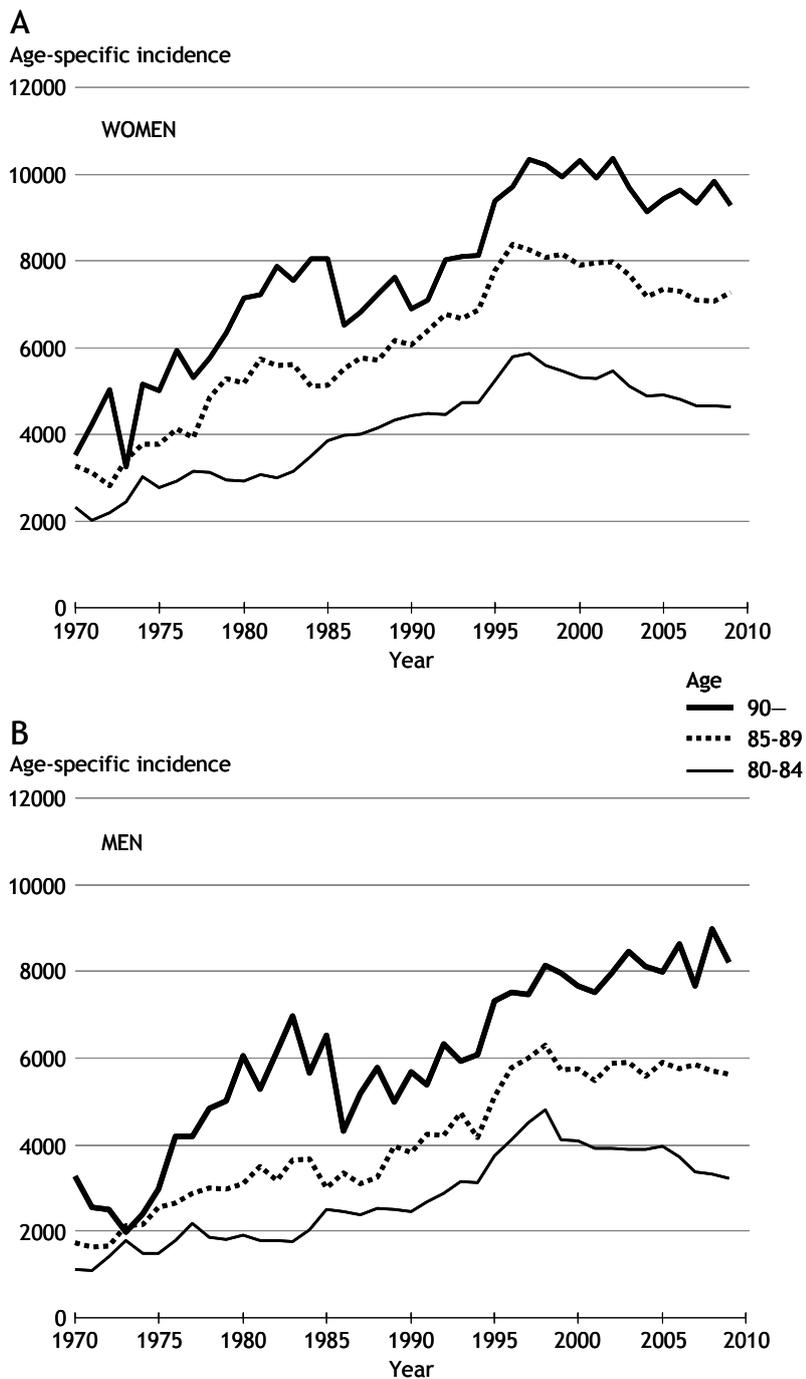


Fig 2. Age-specific incidence (per 100 000 persons) of fall-induced injuries among elderly (A) women and (B) men in Finland in 1970-2009.

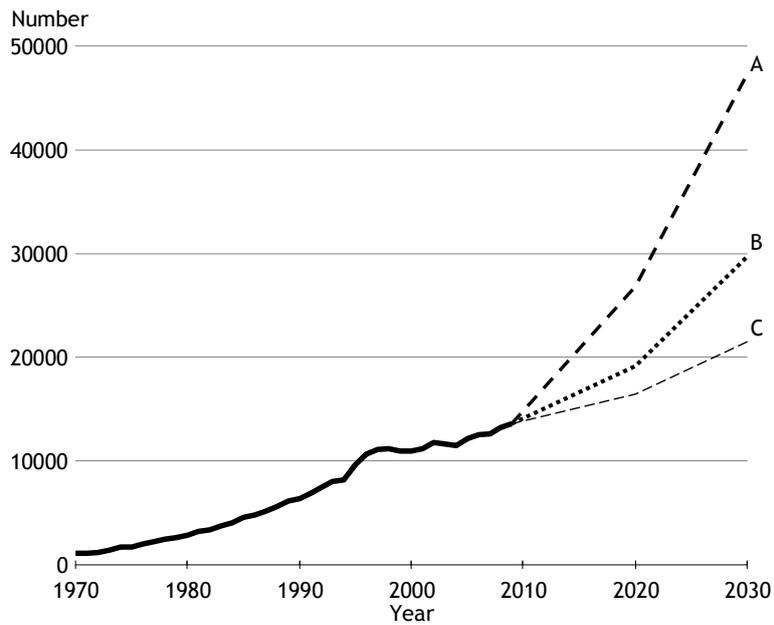


Fig 3. The number of fall-induced injuries among elderly Finns aged 80 years or older in 1970-2009 and prediction of the development until the year 2030. In the curve A the prediction has been made assuming that the age-adjusted incidence of fall-induced injuries continues to rise at the average rate observed during 1970-2009. The curve B indicates prediction in which the incidence becomes stabilized to the 2009 level, and the curve C denotes to prediction in which the incidence continues to decline at the average rate observed since the late 1990s.

Continuous decline in incidence of hip fracture: nationwide statistics from Finland between 1970 and 2010

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Abstract

Summary We determined the current trend in the number and incidence of hip fracture among persons 50 years of age or older in Finland between 1970 and 2010. After a clear rise until the late 1990s, the incidence of hip fracture has continuously declined.

Introduction Hip fractures are a major public health issue associated with excess morbidity and mortality. We determined the current trend in the number and incidence (per 100,000 persons) of hip fracture among older adults in Finland, an EU country with a well-defined Caucasian population of 5.4 million people.

Methods We took into account all persons 50 years of age or older who were admitted to hospitals for primary treatment of hip fracture between 1970 and 2010.

Results The number of hip fractures rose sharply till the end of 1990s (from 1,857 in 1970 to 7,122 in 1997), but since then, the rise has leveled off (7,594 fractures in 2010). Similarly, the age-adjusted incidence of hip fracture

increased until 1997 but declined thereafter. The decline was especially clear in women whose age-adjusted incidence was 515.7 (per 100,000 persons) in 1997 but only 382.6 in 2010. In men, the corresponding incidence was 245.3 in 1997 and 210.7 in 2010. The number of hip fractures will increase 1.8-fold by 2030 even with the current 2010 incidence rates because the size of the 50-year-old or older population is likely to increase sharply in the near future.

Conclusions The declining trend in the incidence of hip fracture in Finland has continued through the entire first decade of the new millennium. Reasons for this development are uncertain, but possible explanations include increased average body weight, improved functional ability among elderly Finns, and specific measures to prevent bone loss and reduce the risk of falling.

Keywords Elderly adults · Epidemiology · Hip fracture · Incidence · Time trends

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Introduction

Injurious falls of older adults are a major public health concern in modern societies [1, 2], and majority of the recorded injuries are bone fractures [3, 4]. More than any other type of fracture, hip fractures are associated with functional impairment, disability, morbidity, and mortality [5–7]. Thus, hip fractures are a problem, not only on the well-being of older people but also on the health care systems and their economy.

Previously, we reported that the rise in the incidence of hip fracture in Finland until 1997 [5] was followed by declining fracture rates [7]. We have now followed the population another 6 years (to the end of 2010) to analyze the most recent data on the incidence of hip fractures and to assess whether the decline in fracture rates has continued.

Methods

As previously [7], the data of the hip fractures were obtained from the Finnish National Hospital Discharge Register. This statutory, computer-based register is the oldest nationwide discharge register in the world (in operation since 1967) and provides reportedly reliable data for severe injuries in Finland, a country with a well-defined Caucasian population of 5.4 million people [8–10]. To calculate the incidence rates of fracture, annual midyear populations were taken from The Official Statistics of Finland, the statutory computer-based population register of the country [11].

Hip fractures were identified by assessing primary and secondary diagnoses with the code class 820 of the International Classification of Diseases versions eight (ICD-8) (1970–1986) and nine (ICD-9) (1987–1995), and the code class S72 of the ICD-10 (1996–2010) [7]. For each observation year, one person was counted only once. Incidence rates of hip fracture were calculated for both sexes and were expressed as the number of cases per 100,000 50-year-old or older persons per year. For calculation of the age-adjusted fracture rates, age adjustment was done by direct standardization using the mean population between 1970 and 2010 as the standard population.

The hip fracture data were drawn from the entire 50-year-old or older population of Finland, which was 1,137,945 in 1970 and 2,087,624 in 2010. Thus, the given absolute numbers and incidence rates of hip fractures were not cohort-based estimates but actual complete population results, and therefore, the study, in full agreement with our previous studies [1, 3, 5, 7], did not use statistical analyses with confidence intervals intrinsically needed for cohort- or sample-based estimations.

Results

The number of hip fractures among Finns 50 years or older rose considerably between 1970 and 1997 from 1,857 to 7,122 (Fig. 1a). Since then, the rise has leveled off, the number of hip fractures being 7,594 in 2010. Due to this development and the continuous increase in the population at risk, the crude incidence of hip fracture have decreased in Finland since 1997 (Fig. 1a). Similarly, in both genders, the age-adjusted incidences of hip fracture rose until 1997 but have continuously declined thereafter (Fig. 1b). The decline has been especially clear in women among whom the age-adjusted incidence was 515.7 (per 100,000 persons) in 1997 while only 382.6 in 2010. In men, the corresponding incidence was 245.3 in 1997 and 210.7 in 2010.

In women as well as men, the age-specific incidence of hip fracture has declined in the three oldest age groups since 1997 (age groups 65–74, 75–84, and 85+), while in the youngest age group (50–64 years), the incidence has

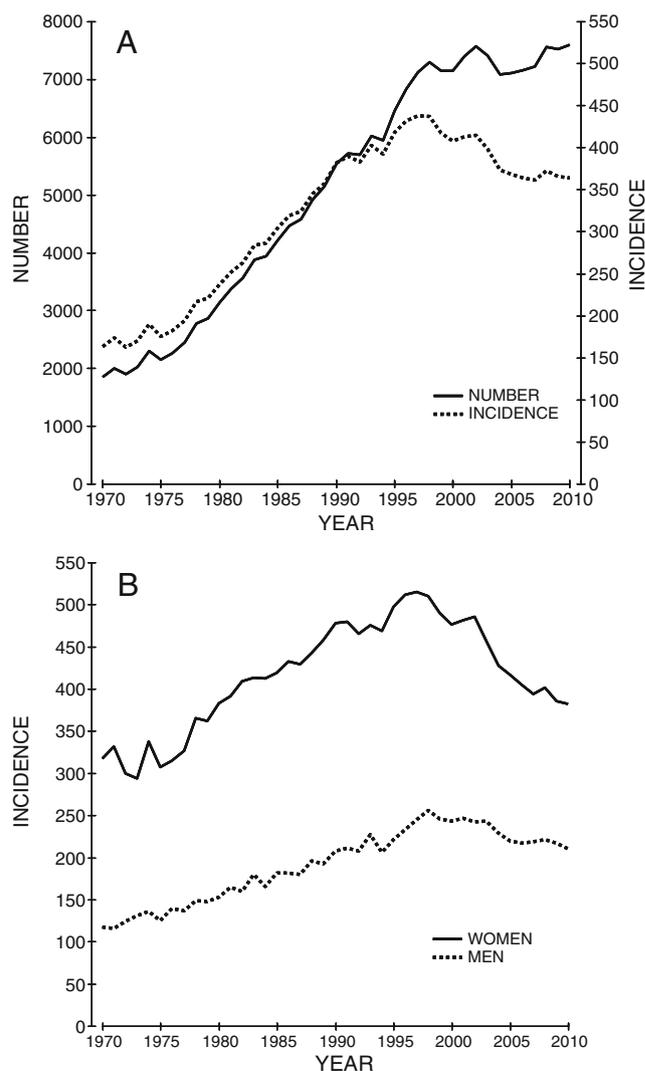


Fig. 1 Hip fractures in Finland in people ≥ 50 years of age between 1970 and 2010. **a** Number and crude incidence (per 100,000 persons). **b** Age-adjusted incidence (per 100,000 persons)

remained rather stable during 1997–2010 (Fig. 2). In contrast with the declined fracture incidence, the average age of the Finnish hip fracture patients has risen steadily between 1970 and 2010: from 74.7 to 81.6 among women and from 70.2 to 76.0 among men.

Despite the declined fracture incidence during the recent decade, it is of interest that if the size of the 50-year-old or older Finnish population increases as predicted (from 2.09 million in 2010 to 2.52 million in 2030) and the incidence of fractures is to become stabilized to the current 2010 level, the number of hip fractures will increase in Finland between 2010 and 2030, up to about 10,000 annual hip fractures by the year 2020 and about 13,500 annual hip fractures by the year 2030 (1.3- and 1.8-fold increases compared to the number in 2010). Thus, a continuous decline in the incidence of hip fracture will be needed to limit the rise in the fracture numbers.

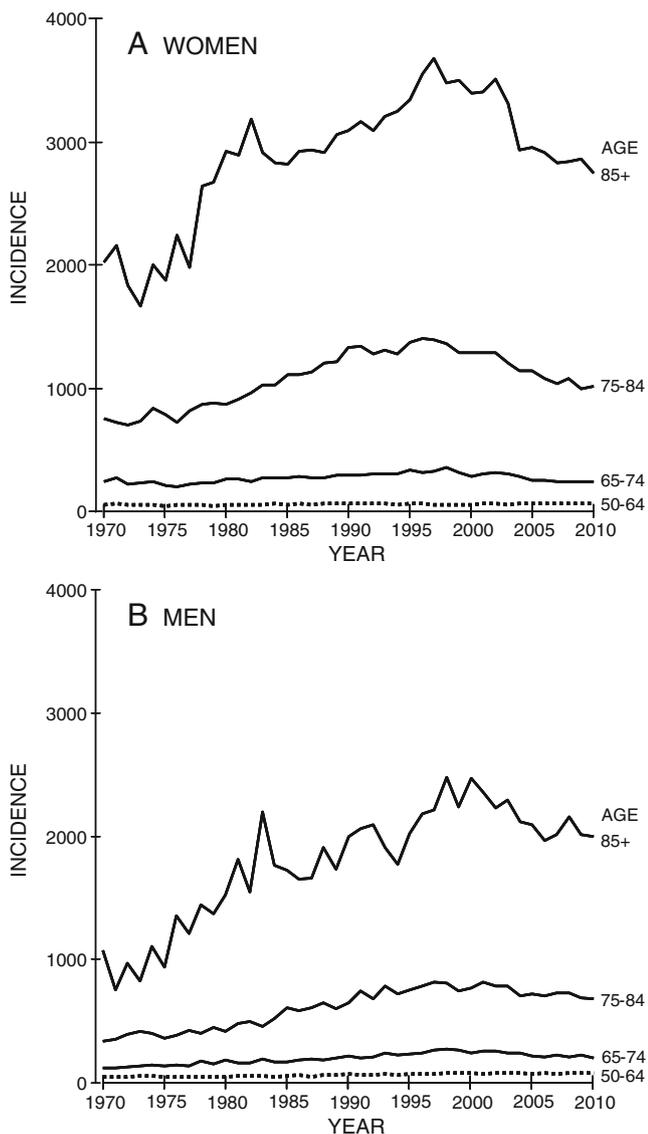


Fig. 2 Age-specific incidence (per 100,000 persons) of hip fracture in Finland in people ≥ 50 years of age between 1970 and 2010: **a** women; **b** men

Discussion

The current study shows that in Finland, the incidence of hip fractures has decreased during the entire first decade of the new millennium. Although the age-adjusted incidence (that is, the average individual risk) of fractures has declined in both sexes, the decline has been especially clear among women.

Our fresh epidemiologic data on the incidence of hip fractures are in line with other recent studies from Scandinavia [12, 13], Netherlands [6], Australia [14], Canada [15, 16], and USA [17–20]. They all report declining rates of hip fracture. On the other hand, there have also been reports on rising incidences of hip fractures in some areas, such as Germany [21] and Asia [22].

A major limitation in our study was that the exact reasons behind the continuous decline in hip fracture incidence are uncertain. As we previously speculated, a cohort effect toward healthier elderly populations could partly explain the development: early-life risk factors (such as perinatal nutrition) may have had stronger effect on the fracture risk in the earlier than later birth cohorts [7]. The higher average age of present hip fracture patients might support this assumption: between 1970 and 2010, the average age of a hip fracture patient rose 7 years among women and 6 years among men in Finland.

As the incidence of hip fracture increases with age, one explanation for the observed decline in the rates of hip fractures could be that the average functional ability of elderly people in Finland has improved [23]. Improved muscle strength, balance, and coordination among today's elderly people could reduce the risk of falling leading to hip fractures, compared with their perhaps physically less active age-mates in earlier decades [24, 25]. As women have reportedly higher incidence of injurious falls than men [26], one may speculate about whether the functional ability of women has improved more than that of men thus accounting for the steeper decline in hip fracture incidence. Also, improved prevention and treatment of chronic diseases might have affected to the decline in hip fracture incidence, since for example cardiovascular diseases have been associated with hip fractures and their incidence has declined considerably during recent decades [27].

Additionally, nutritional changes may have contributed to the development of hip fractures. A low BMI is a strong risk factor for hip fracture [28], whereas a high BMI or overweight is protective, most likely via improved bone and muscle strength and direct padding effect of the fat tissue on the hip. The prevalence of obesity (BMI 30 kg/m² or over) has increased by 70 % in Finnish men and by 30 % in Finnish women since the 1980s [29] and currently 18 % of our men and 16 % of our women are obese [30]. This factor could have reduced the average risk of hip fracture.

Lastly, actions to prevent and treat osteoporosis and targeted interventions to reduce the risk of falling could partly explain the declining hip fracture incidence. More specifically, increased availability and use of bone mineral density testing, exercise, non-smoking campaigns, calcium, vitamin D, hormone replacement therapy, and bone-specific drugs could have contributed to the incidence of osteoporosis and hip fractures. For example, smoking, which is a clear risk factor for hip fracture, has reduced in Finnish men from the prevalence of 80 % in 1940s to current level of 22 % [30, 31]. In Finnish women, the highest prevalence was in 1990s (20 % smoke) while the current prevalence of smokers is 15 % [30, 31]. On the other hand, concerning some methods, such as bone testing and osteoporosis medication, decreasing fracture rates were seen even before their widespread availability and

use. The drug use has always concerned a minority of the elderly population only (currently less than 5 % use bone-specific drugs), and the pharmaceutical interventions of women (estrogen) cannot explain the declining pattern in men [7, 13, 15]. In addition, some methods, such as exercise, smoking, calcium, and vitamin D, lack of good evidence for their secular change among elderly Finns [7, 29].

The programs to prevent falling and minimize fall severity (by strength and balance training, modification of environmental hazards, use of hip protectors and gait-stabilizing antislip devices, correction of visual impairment, reducing psychotropic medication, and vitamin D and calcium supplementation) could partly explain the continuing decrease in hip fracture rates [24, 25]. Although the same limitations apply here as noted above for osteoporosis, these measures might be feasible for larger implementation, since falls prevention programs for elderly people have been shown to be effective and the preventive measures can be organized cost-effectively [32, 33].

In conclusion, the declining trend in the incidence of hip fractures has continued in Finland during the entire first decade of the new millennium. Since the rapid and continuous aging of the population will increase the burden of hip fractures in the near future, further decline in the incidence is needed to limit the rise in the absolute number of fractures.

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Conflicts of interest None.

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RESEARCH LETTER

Incidence of Fall-Related Traumatic Brain Injuries Among Older Finnish Adults Between 1970 and 2011

To the Editor: Traumatic brain injury (TBI) is a major cause of hospitalization, disability, and death worldwide, and among older adults, falling is the most common cause of TBI.¹ We reported that the number and incidence of adults aged 80 years or older admitted to the hospital due to fall-induced TBI in Finland increased from 1970 through 1999.² We now report follow-up of this population through 2011.

Methods. The Finnish National Hospital Discharge Register is a statutory, nationwide, computer-based register that provides reliable data for severe injuries among the Finnish population of 5.4 million people.^{3,4} Annual mid-year populations were taken from the official statistics of Finland.

For the entire period from 1970 through 2011, a fall-induced TBI in an adult aged 80 years or older was defined as a head injury that occurred as a consequence of a fall from a standing height of 1 m or less and resulted in hospitalization. Age-adjusted and age-specific incidences of TBI were calculated for both sexes and were expressed as the number of cases per 100 000 adults aged 80 years or older per year.

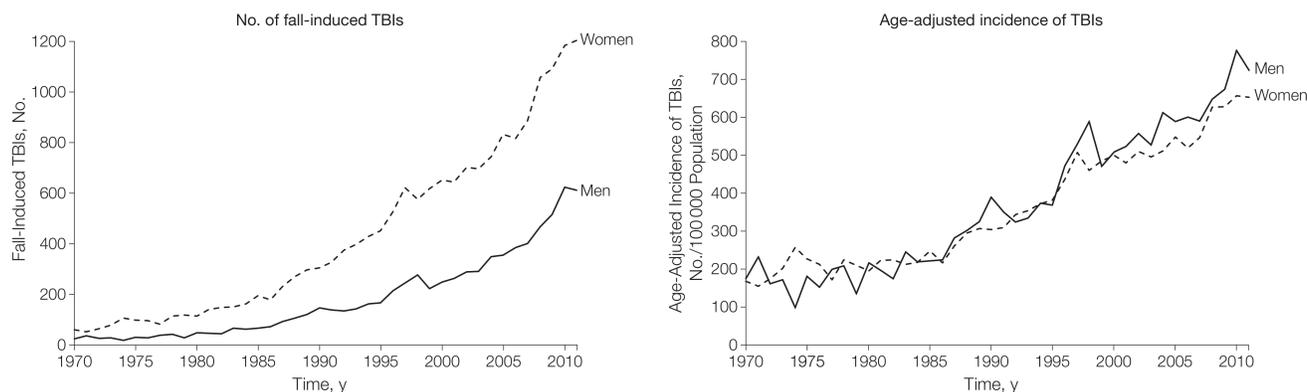
The age adjustment was performed by direct standardization using the mean population aged 80 years or older from 1970 through 2011 as the standard population. Calculations for the age-specific incidences were performed in 5-year age groups (80-84, 85-89, and ≥ 90 years) and the mean incidence from 1970 through 1974 was compared with the incidence from 2007 through 2011.

The study was approved by the UKK Institute for Health Promotion Research institutional review board. The data were analyzed using SPSS version 20 software (SPSS Inc).

Results. The total number of older Finnish adults with a fall-induced TBI increased considerably from 60 women and 25 men in 1970 to 1205 women and 612 men in 2011 (FIGURE). The age-adjusted incidence of TBI (per 100 000 persons) also showed an increase from 168.2 women in 1970 to 653.6 in 2011 (an increase of 289%) and from 174.6 to 724.0, respectively, in men (an increase of 315%; Figure).

The mean age-specific TBI incidence rates (per 100 000 persons) from 1970 through 1974 vs 2007 through 2011 in women were 176 vs 475 (aged 80-84 years), respectively, 194 vs 767 (aged 85-89 years), and 262 vs 989 (aged ≥ 90 years) and the respective incidence rates in men were 164 vs 551 (aged 80-84 years), 143 vs 847 (aged 85-89 years), and 281 vs 1222 (aged ≥ 90 years).

Discussion. Our 40-year follow-up shows that the number and age-adjusted incidence of fall-induced TBI in Finnish men and women aged 80 years or older increased considerably between 1970 and 2011. Compared with the data in our previous study,² the increase has continued since 1999.

Figure. Fall-Induced Traumatic Brain Injuries (TBIs) in Finnish Women and Men Aged 80 Years or Older Between 1970 and 2011

Study strengths include unchanged TBI definition, a population-based complete, accurate, and current database, and long follow-up. The limitations include the lack of information on reasons and risk factors for falls and severity of injury, and unknown generalizability.

Our findings are in line with other recent observations of fall-related TBI among elderly adults,^{1,5} but the exact reasons for the ongoing increase are largely unknown. We do not know whether the increase in fall-induced TBI is related to an increase in falls or to an increase in TBI after a fall. Currently, older adults (aged ≥ 80 years), or at least the frailest among them, may fall more often and more seriously than their predecessors because they live longer and have many chronic disorders.^{2,3} In addition, some strong external risk factors for falling, such as polypharmacy, may have become more common among older adults.^{2,3,6}

Changes in living arrangements, impaired balance and vision, sensory neuropathy, alcohol consumption, and increased use of anticoagulants also may have contributed. Further studies are needed to better understand the reasons for the increase in fall-related TBI in older persons (aged ≥ 80 years) so that effective interventions for falls and injury prevention can be initiated.

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Research, Tampere, Finland; and Department of Trauma, Musculoskeletal Surgery, and Rehabilitation, Tampere University Hospital, Tampere, Finland (Dr Kannus).

Author Contributions: Ms Korhonen had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Korhonen, Niemi, Parkkari, Kannus.

Acquisition of data: Korhonen, Niemi, Kannus.

Analysis and interpretation of data: Korhonen, Niemi, Parkkari, Sievänen, Kannus.

Drafting of the manuscript: Korhonen, Niemi, Parkkari, Kannus.

Critical revision of the manuscript for important intellectual content: Korhonen, Niemi, Parkkari, Sievänen, Kannus.

Statistical analysis: Korhonen, Niemi.

Obtained funding: Korhonen, Kannus.

Administrative, technical, or material support: Korhonen, Niemi, Parkkari, Sievänen, Kannus.

Study supervision: Parkkari, Kannus.

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Rapid increase in fall-induced cervical spine injuries among older Finnish adults between 1970 and 2011

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Abstract

Background Fall-related injuries in older adults are a major public health challenge.

Methods We determined the current trends in the number and age-adjusted incidence of fall-induced severe cervical spine injuries among older adults in Finland by taking into account all persons 50 years of age or older who were admitted to Finnish hospitals for primary treatment of these injuries between 1970 and 2011. Similar patients aged 20-49 years served as a reference group.

Results The number of fall-induced cervical spine injuries among older Finns rose six fold from 59 in 1970 to 372 in 2011. The age-adjusted incidence of injury (per 100 000 persons) was higher in men than women throughout this period and showed a clear increase from 1970 to 2011: from 8.5 to 20.3 in men, and from 2.8 to 11.7 in women. In both sexes, the increase was most prominent in the oldest age group, persons aged 70 years or older. In the reference group, the injury incidence did not rise by time.

Conclusions The number and incidence of fall-induced severe cervical spine injuries among older Finns increased considerably between 1970 and 2011. An increase in the average risk of serious falls may partly explain the phenomenon. Wide-scale fall and injury prevention measures are urgently needed because further ageing of the population is likely to worsen the problem in the near future.

Introduction

Falls and fall-related injuries in older adults are a serious public health concern in contemporary societies with aging populations [1, 2]. In older patients, cervical spine injury commonly occurs after a relatively minor trauma [3, 4] and majority of these injuries are caused by falls [5, 6, 7]. Of all fall-induced injuries, a spinal cord injury or fracture to the cervical spine (alone or in combination) is a relatively rare event [8] but one of the most severe and disabling condition for the victims with high mortality [6,9].

Previously, we reported that the number and age-adjusted incidence of fall-induced severe cervical spine injuries showed an alarming rise among Finns 50 years or older between 1970 and 2004 [10]. We have now followed the population another 7 years (to the end of 2011) to analyse most recent changes and to assess whether the increase in injury rates has continued.

Materials and methods

Finland is an EU-country with a well-defined Caucasian population of 5.4 million inhabitants in 2011 (4.6 million in 1970). The data of the fall-induced cervical spine injuries occurring in Finland from 1970-2011 originates from the Finnish Hospital Discharge Register (FHDR). This statutory, computer-based register is the oldest nationwide discharge register in the world, and provides reportedly reliable data for severe injuries and their causes among the Finnish population [1, 11]. In this epidemiologic study, a fall-induced cervical spine injury was defined as an injury (fracture, cord injury, or their combination) that occurred in a person aged 50 years or older as a consequence of a fall from standing height of 1 m or less and resulted in hospitalisation of the victim. Also a younger reference group, all patients aged between 20 and 49 years, who were admitted to hospitals in Finland for primary treatment of an acute cervical spine injury between 1970 and 2011, were selected from the FHDR.

In calculating the gender-specific age-adjusted injury incidence (per 100 000 persons), the age adjustment was done by direct standardisation using the mean population of persons aged 50 years or older between 1970 and 2011 as the standard population. The annual midyear populations were taken from the Official Statistics of Finland, the statutory, computer-based population register of the country [12].

The age-specific incidences (per 100 000 persons) were calculated for three 10-year age groups (50-59, 60-69, and >70 years). For data validation and comparison, the incidence of injury was also studied in the younger reference group.

In each of the above noted study groups, the future incidence prediction was assessed using a linear regression model, and then, within each age and sex group, the predicted absolute number of injuries in 2030 was obtained by multiplying the incidence by the estimated number of inhabitants. This estimation was obtained from the Finnish Population Projections 2010-2030 [13].

The absolute numbers and incidences of fall-induced cervical spine injuries were not cohort-based estimates but actual population-based results drawn from the entire population of Finland. Therefore the study, in full agreement with previous investigations [1, 8, 10,14], did not use statistical analyses with confidence intervals.

Results

The number of a fall-induced cervical spine injury among 50 year old or older Finns rose considerably between the years 1970 and 2011, from 59 in 1970 to 372 in 2011 (Figure 1A). The relative increase was 531%. The crude incidences per 100 000 persons were 5.2 and 17.6 (238% increase), respectively.

Throughout the study period, the age-adjusted incidence of injury (per 100 000 persons) was higher in men than women and showed a clear increase from 1970 to 2011: from 8.5 to 20.3 in men, and from 2.8 to 11.7 in women (Figure 1B).

The increase was most prominent in the oldest age group. In men, the age-specific incidence rates (per 100 000 persons) in 1970 versus 2011 were 6.9 vs 9.3 (among men aged 50-59 years), 10.0 vs 20.4 (60-69 years) and 10.5 vs 43.3 (70 years or older). In women, the respective incidence rates were 2.6 vs 3.4 (women aged 50-59 years), 2.1 vs 4.5 (60-69 years) and 3.7 vs 30.9 (70 years or older).

The average age of a patient having a fall-induced cervical spine injury in the 50-year-old or older population increased from 1970 to 2011: from 62 years to 71 in men, and from 65 to 79 in women.

In the younger reference group aged 20-49 years, the annual number and age-adjusted incidence of injury decreased somewhat over time: in 1970, the number and incidence were 85 and 4.5, respectively, and 65 and 3.2 in 2011 (Figure 1, Panels A and B). Across the study period, male predominance was also clear in this younger age group: 79% and 77% of the patients were men in 1970 and 2011, respectively.

If the aforementioned increase in 50-year-old or older people's age-adjusted and age-specific injury incidence continues at the same rate as in 1970-2011 and the size of this population in Finland increases approximately 18% (as predicted for the next 20 years) [13], the number of fall-induced cervical spine injuries in this population will be over 50% higher in the year 2030 (about 580 injuries) compared to 372 injuries in 2011 (Figure 1C).

Discussion

In this nationwide study we described the trends of fall-induced severe cervical spine injuries in the entire Finnish adult population between 1970 and 2011. We found that the injury incidence increases with age, is higher in men than women, and that the overall number as well as the age-adjusted and age-specific incidence of these injuries clearly rose from 1970 to 2011. In the younger adults aged 20-49 years, such an increase was not seen.

Previous studies have also reported increasing numbers of fall-induced cervical spine injuries among older adults, including Sweden [15], USA [16] and Iceland [17]. Further ageing of the populations is likely to increase the problem so that by the year 2030 Finland, for example, is likely to face 50% rise in fall-induced injuries of the cervical spine among persons 50 years of age or older (up to 580 victims per year).

The majority of cervical spine injuries seem to occur at the upper cervical spine (C1-C2 level) [4, 15, 18] making the treatment (stabilisation and immobilisation with halo brace, rigid collars or surgery) [19] very hard for the patient [20] and prone to complications [6, 21]. Furthermore, elderly people's cervical spine injury has been associated with high mortality [6, 9]. In cervical spine fractures, the risk of death has been reported to be as high as 28% at one year [9]. High mortality, in turn, has been associated with neurological involvement [21], increased age and comorbid conditions [9], but even an isolated cervical spine injury can result in death or discharge to a long-term care facility) [6]. At the other end of the outcome spectrum, there have been reports about patients regaining good function and returning home after discharge from hospital [21, 22]. Concerning injury costs, literature does not provide cost analyses for fall-induced cervical spine injuries of older adults, but in general it is well known that injuries of the head region are one of the most costly fall-induced injuries in the ageing population [23].

The exact reasons for the rise in the elderly people's age-adjusted and age-specific incidence of fall-induced cervical spine injuries are uncertain [1, 2, 10]. An increase in the average risk of falling - caused by impaired muscle strength, balance, and reaction time - may partly explain the phenomenon. On the other hand, today's older people may have more serious consequences of falling than their predecessors; that is, an increasing number of less-healthy and functionally less-capable elderly people are, among others, now surviving to older ages (e.g. because of more effective health care and life-extending treatments and medication) and this may underlie increased incidence in severe falls [2, 14]. In addition, degenerative changes (with diminished flexion-extension mobility and spinal stenosis) and osteoporosis in the cervical spine of older adults increase the risk for spinal injury after a relatively minor trauma [22].

It is of interest that while the overall incidence of elderly people's fall-induced injuries has declined during the new millennium in Finland [8], the steep rise in the incidence of severe injuries to the head [14] and cervical spine has continued. The reasons behind these differences are speculative but, as noted above, secular changes in the severity and mechanisms of falling could partly explain the phenomenon. A recent video study on authentic falls of older adults in long-term care facilities showed that head impact occurred in surprisingly many cases (37 %) and that head impact was particularly common in forward falls [24].

In this study of fall-induced severe cervical spine injuries, the age-adjusted injury incidence was higher in men than women. Previously we have made a similar observation in older adults' fall-induced traumatic brain injuries [14] and fall deaths [25]. Since the general incidence of falling is higher in elderly women than elderly men [1, 2, 26], it can be hypothesised that elderly men have a greater risk for severe outcomes of falls than their female counterparts. Taller and heavier body (ie, higher impact energy while falling), higher consumption of alcohol, poorer nutritional status, greater occurrence of comorbidities and greater risk-taking behavior among older men compared to older women may explain this gender disparity [25]. Further studies are, however, needed to confirm our observations and elaborate the reasons for the difference between genders.

Our study confirms the previous findings that the average age of the patients with an acute traumatic spinal cord injury is increasing [16, 27]. Nevertheless, effective falls prevention programmes among older adults has potential to reduce serious fall-related injuries and subsequent emergency department visits, hospitalizations, nursing home placements, functional decline, and mortality [2, 28]. Multifactorial interventions aimed at reducing the number of falls of elderly persons by simultaneously modifying many of the predisposing and situational risk factors for falls have shown promising results [2, 28, 29, 30]. Also, single interventions, such as strength and balance training, withdrawal of psychotropic medication, calcium and vitamin D supplementation, correction of visual impairment, a multifaceted podiatry care, gait-stabilizing shoe devices, and home-hazard assessment and modification, can be effective [2, 28,29]. Moreover, recent analysis of head impacts during falls suggested that backward rotation during decent could protect the head, but hand impact as protective response appeared ineffective [24]. Thus, improving upper-limb strength and teaching falling techniques were suggested to reduce fall-related head impacts in older adults [24].

Taken together, the number of fall-induced severe cervical spine injuries among Finnish adults 50 years of age or older has increased between 1970 and 2011 with a rate that cannot be explained merely by demographic changes. Therefore, wide-scale falls and injury prevention actions should be urgently adopted to control the development.

Key points

- The incidence of fall-induced severe cervical spine injuries among older Finns increased sharply from 1970 to 2011
- The injury incidence increased with age and was clearly higher in men than women
- Effective fall and injury prevention is needed, because the elderly population will grow rapidly in the near future

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Conflict of interest

The authors state that they have no conflicts of interest.

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Figure legend

Figure 1. Number (A) and age-adjusted incidence (per 100 000 persons) (B) of fall-induced severe cervical spine injuries in Finland in people 50 years of age or older between 1970 and 2011, and prediction of the number of injuries until 2030, as calculated with a regression model (C). The number of people in this age group was 1.14 million in 1970 and 2.12 million in 2011, and is estimated to increase to 2.50 million in 2030. For comparison, the number and incidence of similar injuries in patients aged 20-49 years are shown with a dotted line in (A) and (B).

