Hand and Wrist Injuries

Trends and Societal Consequences

Dennis de Putter

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Hand en pols letsels

trends en maatschappelijke consequenties

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Aan mijn ouders

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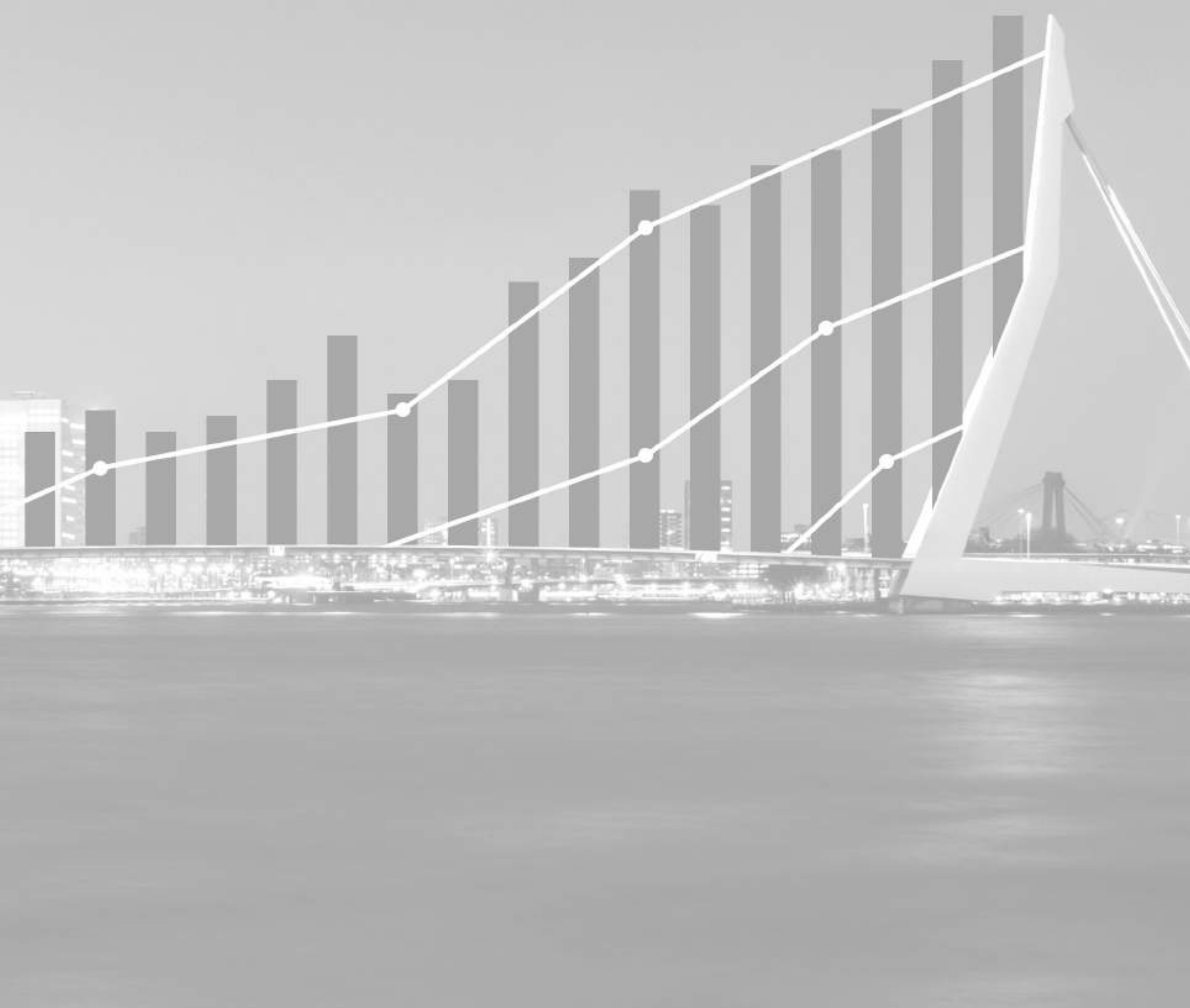
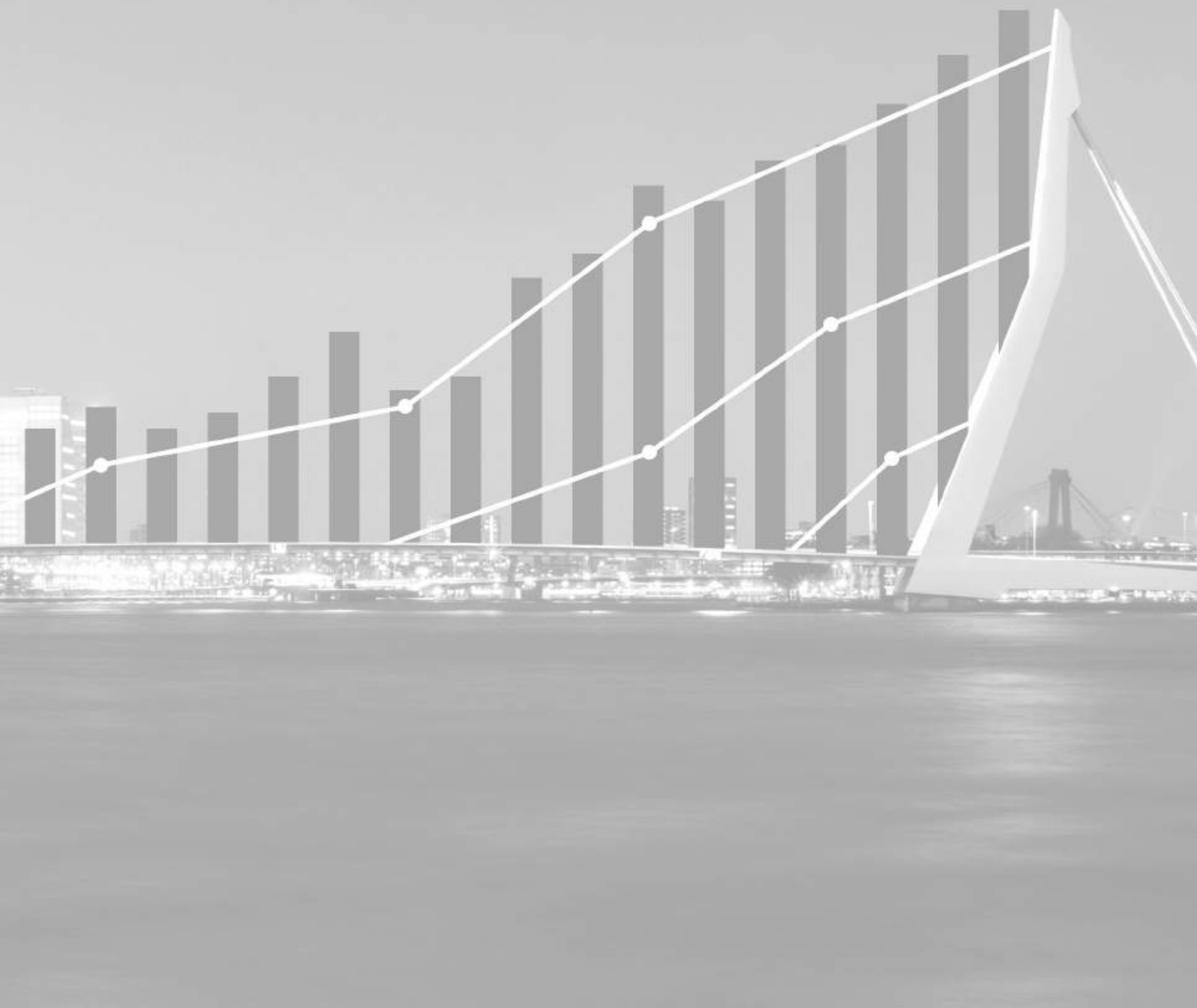


Chapter 1

General introduction



GENERAL INTRODUCTION

Hand and wrist injuries are a frequent cause of Emergency Department (ED) visits.[1-6] A study by Larsen et al. showed that approximately 287,000 hand injuries were treated at the ED in the Netherlands in the period 1997-1998, resulting in an incidence of 1800 per 100,000 inhabitants per year.[7]

Previous clinical studies on hand and wrist injuries have shown that many of these injuries are disabling and result in functional limitations. A substantial part of patients with hand and wrist injuries may have residual impairment and pain after the injury.[8-13] However, the impact of hand and wrist injuries at population level is still largely unknown. Although, due to their high frequency[14], hand and wrist injuries may have important consequences for public health and for healthcare policy, population-based data on trends and causes of hand and wrist injuries are scarce. Epidemiologic data are important for healthcare providers to plan for appropriate provision of care, and for policymakers to adjust prevention strategies and healthcare policies for the future.

In this thesis, we analysed recent trends and the impact of hand and wrist injuries at population level in the Netherlands. In part I, we reflect on epidemiological trends in hand and wrist injuries among different age categories, as well as on the main causes of these trends. In part II, we focus on the societal consequences of these injuries to the Dutch society.

PART I: TRENDS

Among the spectrum of hand and wrist injuries, fractures of the wrist rank first in terms of frequency and morbidity, with an estimated incidence of 400 fractures per 100,000 inhabitants per year.[15] Wrist fractures are not equally prevalent at all ages. There is a bimodal age distribution, with a peak in adolescence and a second peak in the population of 50 years and older. The incidence of paediatric fractures is higher in boys than in girls, which appears to coincide with the age of growth spurt, while the second peak in the older population is more likely related to reduced bone strength.[16-18]

While the incidence and demographics of childhood wrist fractures have been described in several previous studies, incidence rates change over time due to changes in activities and risk factors. Participation in sports, for example, is important to improve general health and fitness in childhood, but may also lead to injuries.[19,20] This in particular concerns contact sports, such as soccer, one of the most popular team sports worldwide. While injury prevention initiatives targeting soccer players may be valuable, epidemiological studies exploring trends and determinants of injuries within this group are scarce.[21-25]

So far, only a few population-based studies have examined the incidence of paediatric wrist fractures over a longer, uninterrupted time interval. A study from the US showed that the incidence of distal forearm fractures increased from 1969 to 2001, with some levelling-off in the last three years of the study.[26] A study from Finland showed an increase of forearm and upper arm fractures in 2005 compared with data from 1983, despite an overall decrease of paediatric fractures.[27] The reasons for these changes in incidence have not been elucidated, although several contributing factors have been suggested, such as changes in recreational activities or sports, and bone mineral density.[28] Since different interventions may be aimed at preventing wrist fractures, it is important to detect changes in the incidence of these injuries and their underlying causes.

In the older population, wrist fractures (see Table 1) are the most common upper extremity fracture, and often are the result from an underlying osteoporosis.[29,30] Previous studies have shown geographical variation in incidence of these fractures, reporting higher rates in North America and Europe compared with Asia.[31-41] With the growing older population and an increasing life expectancy, the absolute number of fractures and related healthcare demand are expected to increase. Melton et al. reported decreasing wrist fracture rates in Minnesota between 1975 and 1994 in patients aged 35 years and older.[37] More recent epidemiological studies showed diverging trends in hospitalised patients with wrist fractures, varying from increasing rates in France, to decreasing rates in Switzerland and Australia.[38-41]

Figure 1 Abraham Colles (1773-1843) first described the most common distal radius fracture in 1814: 'The posterior surface of the limb presents a considerable deformity; for a depression is seen in the forearm, about an inch and a half above the end of this bone, while a considerable swelling occupies the wrist and metacarpus. Indeed, the carpus and base of metacarpus appear to be thrown backward so much, as on first view to excite a suspicion that the carpus has been dislocated forward.'

Injury surveillance is important to gain insight into trends in the epidemiology and healthcare utilisation of these injuries. This information is essential for healthcare providers for the allocation of healthcare in the future, as well as for policymakers to develop prevention strategies and healthcare policies. The purpose of our studies in part I was to explore and evaluate trends in hand and wrist injuries among children and the elderly , and to identify contributing factors to these trends.

While most previous studies were limited to one or a few hospitals, compared only two or three separate time points to analyse trends or included either non-hospitalised or hospitalised patients, for this thesis, we had access to a comprehensive population-based database covering a period of 15 years (1997-2012). For non-hospitalised cases, we obtained injury cases from the Dutch Injury Surveillance System.[7] The fifteen geographically-separated hospitals in this surveillance system were selected to represent both rural and urban areas, and they form a representative sample of 12% of the total number of injury patients visiting the EDs in the Netherlands (population of 16.5 million inhabitants in 2009). For hospitalised cases, a unique Dutch hospital admission database with 95% national coverage was used.[42-45] This database includes information on the diagnosis, number of hospitalisations and surgical procedures; in this way incidence rates and changes in time trends can be determined.

For definition of hand and wrist injuries, we used the International Classification of Diseases of the World Health Organization (ICD, 10th revision), which defined a wrist fracture as a distal radius fracture, combined fracture of the distal radius and ulna or a carpal fracture (see Table 1). We selected patients based on the registered primary diagnosis of a wrist fracture, according to the diagnostic groups as previously recommended by European experts.[44,45]

Table 1 Diagnostic group wrist fractures and corresponding ICD-10 codes used in this thesis

Blocks of ICD chapter XIX
S52.5: Fracture of the distal radius
S52.6: Fracture of lower end of both ulna and radius
S62: Fracture at wrist and hand level S62.0: scaphoid fracture S62.1: fracture other carpal bones

PART II: SOCIETAL CONSEQUENCES

Healthcare costs and Productivity costs

Injuries to the hand and wrist account for approximately twenty percent of the ED visits. These injuries have a substantial impact on both physical and mental health. However, they may also lead to high healthcare costs and prolonged time off work. As a consequence, these injuries may impose a considerable economic burden to society.[46-49]

Because of increasing healthcare expenditures, economic analyses are considered increasingly important. A previous cost of illness study from the Netherlands showed a relatively high share of healthcare costs due to mental disability, stroke and cancer.[50-52] A clinical study from Sweden showed that productivity costs due to work absenteeism may be larger than healthcare costs.[14] But little is known on the medical costs and production losses due to hand and wrist injuries on population level. Until today, only a few single-centre studies have estimated the costs of hand and wrist injuries, however population-based studies on this topic are lacking. The purpose of two cost analyses in part II of this thesis is to quantify the economic consequences of hand and wrist injuries, and to analyse the underlying causes.

In this thesis, we estimated healthcare costs by using the Burden of Injury Model, as developed by the Consumer Safety Institute and Erasmus MC. Data were extracted from the Dutch Injury Surveillance System and from the National Hospital Discharge Registry to estimate healthcare costs in an incidence-based cost model.[ref] Follow-up data on return to work rates were incorporated in the absenteeism model for estimating the productivity costs.[53,54]

Health-Related Quality of Life

The societal consequences of hand and wrist injuries go beyond the economic impact and includes many other components, such as functional limitations, pain, psychological distress and decreased social interaction. This spectrum of negative consequences is included in generic health-related quality of life (HRQoL) measures, an important patient-reported outcome measure.[55-59] Measures of HRQoL facilitate comparisons of injury consequences with general population norms and the impact of other diseases.

During the last decade, generic HRQoL measures have been increasingly used, which has improved our knowledge on contributing factors to the burden of disease. The Euro-Qol-5D (EQ-5D) questionnaire, a generic HRQoL measure, has been recommended for use in trauma patients by several international consensus groups.[58] This measure is appropriate for comprehensive patient populations, and has been validated and applied in specific groups of injury patients, such as burns and lower extremity injuries.[60,61]

Despite the frequency of hand and wrist injuries, the EQ-5D has not yet been widely used in the population described in this thesis. The purpose of the final study in part II was to quantify the impact of hand and wrist injuries to the Dutch society in terms of health-related quality of life. Information from this study may be important to compare pre- and postoperative outcome, or can be used for cost-effectiveness analyses, benchmarking of hospitals and resource allocation.

AIMS AND OUTLINE OF THIS THESIS

The main research questions to be answered in this thesis are:

1. Which trends and underlying causes can we identify in hand and wrist fractures in the Netherlands? (part I)
2. What is the economic impact of hand and wrist injuries, focused on type of injury and external cause? (part II)
3. What is the impact of hand and wrist injuries on health-related quality of life? (part II)

The epidemiology and trends of hand and wrist injuries over the past decade are considered in part I. **In chapter 2** we examine trends in incidence of wrist fractures in the childhood population, and the main causes of these trends. Subsequently, in **chapter 3**, we investigate trends in upper extremity fractures among young male soccer players. In addition, we aimed to identify possible determinants that are associated with these trends. In **chapter 4**, we examine trends in incidence, hospitalization and surgical treatment of wrist fractures in elderly.

In part II, the consequences for the Dutch society in terms of healthcare costs and productivity costs, and health-related quality of life (HRQoL) are considered. In **chapter 5**, we try to quantify the economic impact of hand and wrist injuries by using economic models to estimate healthcare costs and productivity costs to the Dutch society. We compare these costs with those of other main injury groups. In addition, we examine how these costs are distributed by age category, gender and different subgroups of hand and wrist injuries. In **chapter 6**, we examine the costs and causes of non-trivial hand and wrist injuries (i.e. hand fractures, wrist fractures and complex soft tissue injuries) in the working-age population. In **chapter 7**, we investigated the impact of upper extremity injuries on health-related quality of life in the adult population, and we identify predictors for suboptimal functional outcome in the long-term. Finally, in **chapter 8**, the main results will be discussed, and the implications of these studies and perspectives for further research are highlighted.

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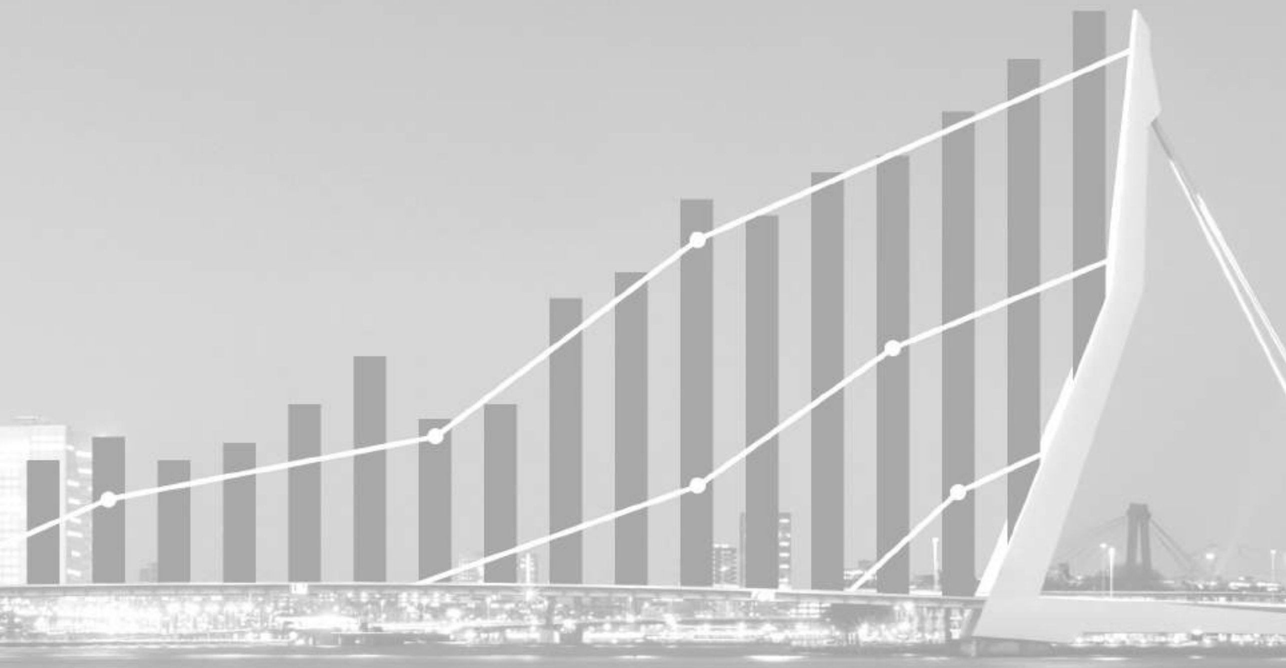
PART I

Trends



Chapter 2

Trends in Wrist Fractures in Children and Adolescents, 1997-2009

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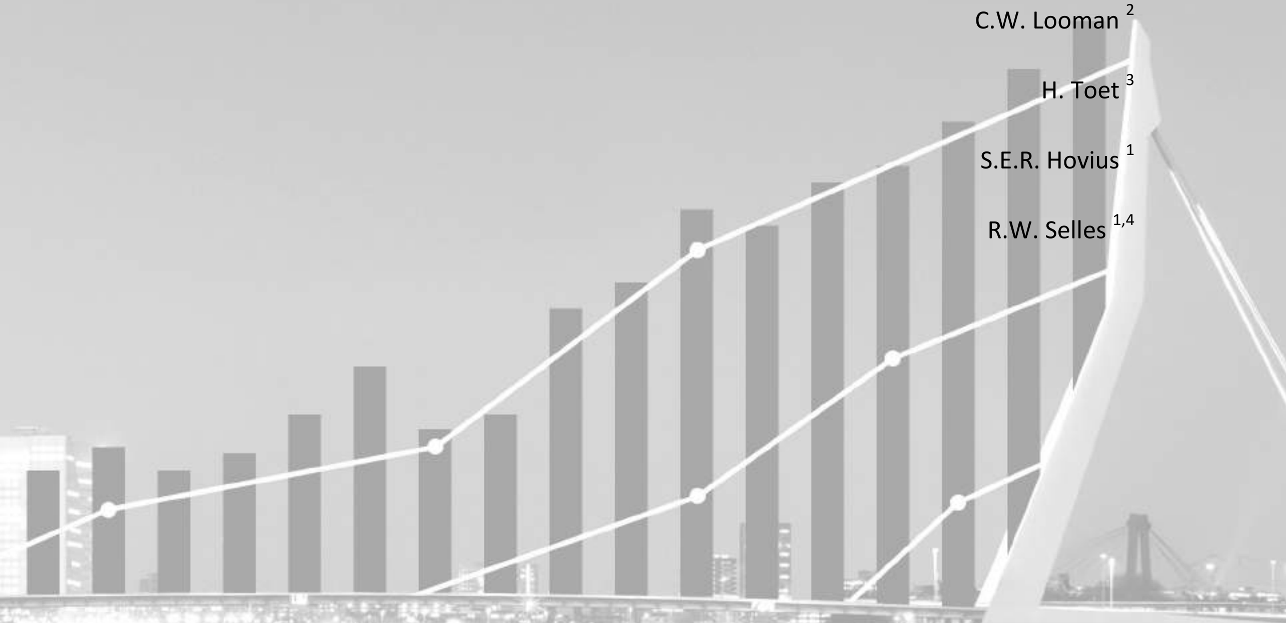

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ABSTRACT

Purpose

Distal radius and carpal fractures in children and adolescents represent approximately 25% of all pediatric fractures. Incidence rates and causes of these fractures change over time due to changes in activities and risk factors. The purpose of this study was to examine recent population-based trends in incidence and causes of wrist fractures in children and adolescents.

Methods

Data were obtained from the Dutch Injury Surveillance System of emergency department visits of 15 geographically distributed hospitals and from the National Hospital Discharge Registry. This included a representative sample of outpatients and inpatients respectively. Incidence rates of wrist fractures per 100,000 person-years were calculated for each year between 1997 and 2009. Trends for children and adolescents aged 5-9, 10-14, and 15-19 years were analysed separately for boys and girls with Poisson's regression.

Results

During the study period, incidence rates increased significantly in boys and girls aged 5-9 and 10-14 years, with the strongest increase in the age group 10-14 years. The observed increases were mainly due to increased incidence rates during soccer and gymnastics at school.

Conclusions

This population-based study has revealed a substantial sports-related increase of the incidence rate of wrist fractures in boys and girls aged 5-9 and 10-14 years in the period 1997-2009.

INTRODUCTION

Distal radius and carpal fractures are frequent and represent approximately 25% of all pediatric fractures.[1-3] While the incidence and demographics of wrist fractures have been described in several previous studies, incidence rates of these fractures change over time due to changes in activities and risk factors.[4-8] Since different interventions may be aimed at preventing, for example, sport injuries, it is important to detect changes in the incidence of these fractures and their underlying causes.

Most previous epidemiological studies on the incidence of these fractures were limited to one or a few emergency departments, compared 2 or 3 separate time points to analyse trends, or included only inpatients or outpatients.[9-15] Only a few population-based studies have investigated the incidence of wrist fractures in children and adolescents over a longer, continuous time period. A study performed in Minnesota showed that the incidence of distal forearm fractures continuously increased from 1969 to 2001 with some levelling-off in the last 3 years of the study.[16] Another study from Finland showed an increase of forearm and upper arm fractures in children aged 0-15 years in 2005 compared with data from 1983 despite an overall decrease of pediatric fractures.[17] The reasons for these incidence changes have not been elucidated, although several contributing factors have been suggested.[4-8,16] Data on population-based trends in childhood wrist fractures are still scarce.

The purpose of this study was to examine recent population-based trends in incidence and causes of pediatric wrist fractures. We analyzed the age- and gender-adjusted incidence rates of these fractures in the Netherlands from 1997 through 2009 and looked at changes due to individual sports.

PATIENTS AND METHODS

Data sources

We evaluated the incidence and causes of wrist fractures among children and adolescents in the Netherlands in the period 1997-2009. Data analysed in this study were obtained from the Dutch Injury Surveillance System for non-hospitalized patients and the National Hospital Discharge Registry for hospitalized patients.[18-21] In the Dutch Injury Surveillance System, all unintentional and intentional injuries treated at emergency departments are recorded, and similar methods in prior studies from other countries are applied.[1,22,23] Fifteen hospitals participated in this injury surveillance system during the study period, including 3 university hospitals and 12 general hospitals. These geographically-separated hospitals were selected to draw from both rural and urban areas and form a sample of 12% of the total number of injury patients presenting at the emergency departments in the Netherlands (population of 16.5 million in 2009). The people using these participating hospitals are representative for the Dutch population in age and gender.[18,24] In this way, extrapolations can be made to national level. In the National Hospital Discharge Registry, individual information on inpatient care is collected on a nationwide basis and has almost 100% coverage.

Injury patients were selected based on the registered primary diagnosis according to the diagnostic groups as previously recommended by European experts.[18,19] We identified all children and adolescents between 0-19 years old with a primary diagnosis of a wrist fracture, defined as a distal radius fracture or a carpal fracture. Data were collected from January 1st 1997 through December 31st 2009. Fracture registration was conducted by the medical doctors at each hospital. Registered data include the patient's name, gender, age, and information on diagnosis, treatment, and discharge. Causes of injury were recorded according to the International Classification of External Causes of Injuries, divided over 6 categories: home, sports, occupational, traffic, self-mutilation, and violence.[25] Sports injuries were also routinely recorded, and we additionally studied the individual sports that contributed most to wrist fractures: soccer, inline skating, and school gymnastics. Sports with lower frequencies were grouped together as 'other' (hockey, bicycling, skiing, running, judo, and horse riding).

Calculation of incidence rates and trends

The patients were divided into gender-specific five-year age groups: children (5-9 years), preadolescents (10-14 years) and adolescents (15-19 years). We excluded children aged 0-4 years because there were not many fractures in that age group. This classification was based on previous epidemiological data on the peak incidence of wrist fractures by age[1,16] and fits differences in activity patterns and injury risks. For each age group, the absolute number of fractures was registered in the injury surveillance system. Because the absolute number of fractures was obtained from a sample, the numbers were weighted to create national estimates. An extrapolation factor was estimated by comparing the number of hospitalized injury patients in the injury surveillance system with the total number of hospitalized injury patients as recorded in the National Hospital Discharge Registry. The age- and gender-specific incidence rates were expressed per 100,000 persons based on the Dutch mid-year population for each study year between 1997 and 2009. The mid-year population sizes for each age group were obtained from Statistics Netherlands. We conducted a Poisson's regression analysis to determine the significance of the observed trends. Confidence intervals of 95% (CI 95%) for the rates were calculated. A P value of < 0.05 was considered as statistically significant. Ethical committee approval is not required for register-based studies in the Netherlands.

RESULTS

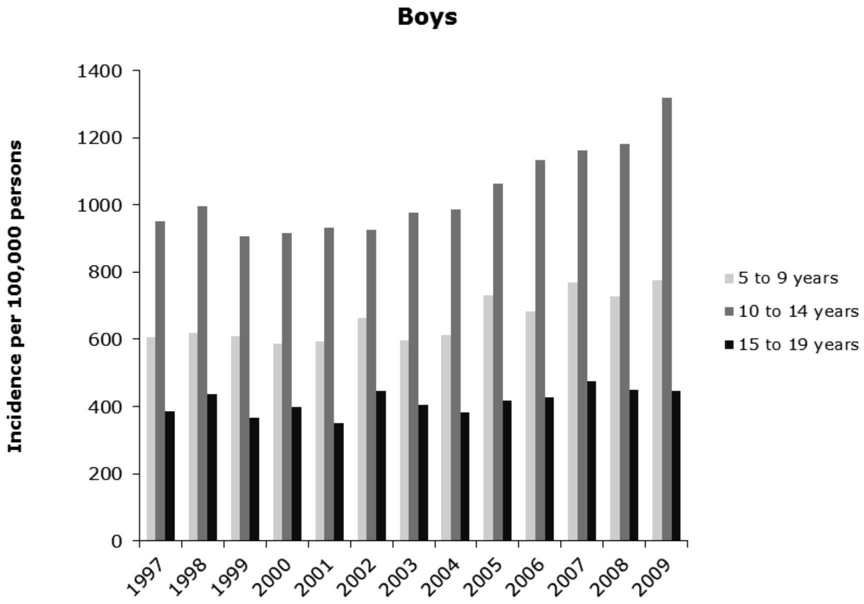
Fracture incidence rates and trends

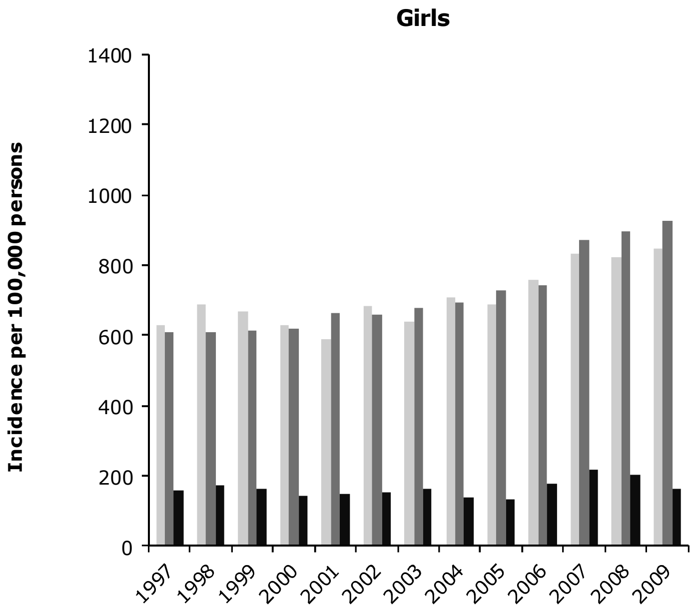
During the study-period, approximately 16,201 (58%) boys and 11,874 (42%) girls aged 5-19 years had a recorded diagnosis of wrist fracture. Around 15,391 boys were treated at an outpatient basis and 810 required surgical intervention. In girls, these numbers were 11,399 and 475, respectively.

In 5-9-year-old boys, we found an increase from 607 per 100,000 persons in 1997, to 756 in 2009 ($p < 0.001$) (Figure 1). In the age group of 10-14 years, the incidence rate increased from 953 to 1318 in the same time period ($p < 0.001$). In the age group 15-19 years, we observed an insignificant increase from 387 in 1997, to 445 in 2009.

In 5-9-year-old girls, the incidence rate increased from 629 in 1997, to 845 in 2009 ($p < 0.001$). In girls aged 10-14 years, we observed an increase from 608 in 1997, to 927 in 2009 ($p < 0.001$). In the age group 15-19 years, the incidence rates remained stable over time.

Figure 1 Incidence rate (per 100,000 persons) of wrist fractures in the period 1997-2009, for boys and girls aged 5-9, 10-14 and 15-19 years





Causes of wrist fractures in children and adolescents

In children 5-9 years old, most fractures were caused by home accidents, while in the age groups 10-14 and 15-19 years the majority of fractures were sports-related (Table 1). For ages 5-9 and 10-14 years, we observed an increase of the incidence of fractures due to home accidents from 1997 through 2009. In addition, we found a relatively strong increase due to sports in all age groups in the same time period. In the oldest age group, the increase of sports-related fractures was accompanied by a decrease in traffic-related fractures.

Because we observed a strong increase of wrist fractures due to sports, we studied changes in the 3 main sports that contributed to these fractures (Table 2). In boys, the majority of sports-related fractures were due to soccer. In the period 1997-2009, the incidence rate of soccer-related fractures rose in all age groups. We observed a relatively large variation in the number of fractures related to inline-skating, with a slightly decreasing trend over time. In all age groups we found an increase in fractures associated with school gymnastics, with the strongest increase in the age group 10-14 years.

In girls, in 1997-1999 most fractures during sports were due to inline-skating. However, in girls aged 10-14 and 15-19 years, from 2004 through 2009, the majority of fractures were due to soccer and school gymnastics. From 1997 through 2009, the incidence of fractures due to soccer and gymnastics increased in all age groups, with the strongest increase related to soccer.

Table 1 Incidence of wrist fractures in children and adolescents (per 100,000 per year) per cause category, summarized in six time-periods between 1997 and 2009

Age Group, y	Cause category	1997/1999	2000/2001	2002/2003	2004/2005	2006/2007	2008/2009
				Boys			
5-9	Home	388	351	410	426	439	435
	Sport	181	138	167	212	227	244
	Traffic	42	39	53	36	43	46
10-14	Home	301	271	290	309	307	342
	Sport	514	527	522	580	691	716
	Traffic	133	116	116	137	129	151
	Occupational, violence and self-mutilation	7	10	7	8	8	6
15-19	Home	77	75	70	51	55	81
	Sport	167	158	207	204	264	256
	Traffic	139	122	122	101	104	100
	Occupational, violence and self-mutilation	19	18	20	15	15	16
				Girls			
5-9	Home	419	399	436	467	517	483
	Sport	211	178	190	185	236	278
	Traffic	42	32	36	46	53	55
10-14	Home	248	258	287	269	281	311
	Sport	313	289	285	351	420	483
	Traffic	107	86	90	93	96	76
	Occupational, violence and self-mutilation	2	2	1	1	2	3
15-19	Home	49	45	48	42	45	49
	Sport	58	53	48	56	80	81
	Traffic	48	43	51	40	38	37
	Occupational, violence and self-mutilation	6	8	7	6	8	7

Table 2 Incidence of wrist fractures in children and adolescents (per 100,000 per year) due to sports, summarized in six time-periods between 1997 and 2009

Age Group, y	Sport	1997/1999	2000/2001	2002/2003	2004/2005	2006/2007	2008/2009
				Boys (Incidence, %)			
5-9	Soccer	69 (38)	64 (46)	76 (45)	107 (50)	119 (52)	122 (50)
	Inline-skating	46 (25)	23 (17)	29 (17)	37 (17)	27 (12)	32 (13)
	Gymnastics	29 (16)	24 (17)	22 (13)	30 (14)	44 (19)	42 (17)
	Other	37 (21)	27 (20)	40 (25)	38 (19)	37 (17)	48 (20)
10-14	Soccer	184 (36)	192 (36)	196 (38)	230 (40)	321 (46)	347 (49)
	Inline-skating	103 (20)	97 (18)	76 (15)	53 (9)	74 (11)	51 (7)
	Gymnastics	94 (18)	115 (22)	101 (19)	123 (21)	139 (20)	136 (19)
	Other	133 (26)	123 (24)	149 (28)	174 (30)	157 (23)	182 (25)
15-19	Soccer	69 (41)	65 (41)	100 (48)	97 (48)	120 (45)	135 (52)
	Inline-skating	15 (9)	15 (10)	14 (7)	10 (5)	15 (6)	11 (4)
	Gymnastics	22 (13)	21 (13)	23 (11)	23 (11)	24 (9)	31 (12)
	Other	61 (37)	57 (36)	70 (34)	74 (36)	105 (40)	79 (32)
				Girls (Incidence, %)			
5-9	Soccer	8 (4)	9 (5)	11 (6)	12 (6)	14 (6)	20 (7)
	Inline-skating	89 (42)	64 (36)	66 (35)	62 (34)	64 (27)	66 (24)
	Gymnastics	27 (13)	24 (14)	35 (19)	34 (18)	36 (15)	51 (18)
	Other	87 (41)	81 (45)	78 (40)	77 (42)	122 (52)	141 (51)
10-14	Soccer	19 (6)	22 (8)	24 (8)	31 (9)	66 (16)	64 (13)
	Inline-skating	93 (30)	88 (30)	69 (25)	76 (22)	79 (19)	59 (12)
	Gymnastics	64 (21)	61 (21)	57 (20)	95 (27)	103 (25)	103 (21)
	Other	137 (43)	118 (40)	135 (47)	149 (43)	172 (40)	257 (53)
15-19	Soccer	5 (8)	4 (7)	6 (13)	12 (21)	16 (20)	19 (23)
	Inline-skating	12 (21)	11 (20)	7 (14)	5 (9)	3 (3)	3 (3)
	Gymnastics	9 (16)	6 (12)	5 (11)	9 (16)	10 (13)	13 (16)
	Other	32 (55)	32 (61)	30 (62)	30 (54)	51 (64)	46 (58)

DISCUSSION

This study presents age- and gender-specific incidence rates for wrist fractures in the Netherlands in the period 1997-2009 using a representative sample of Dutch hospitals. We have shown that the incidence rates increased significantly for boys and girls aged 5-9 and 10-14 years, with the strongest increase in the age group 10-14 years. The observed increases were mainly due to increasing incidence rates during soccer and performing gymnastics at school.

In general, our findings on the magnitude and trends in incidences are consistent with previous studies. Only a few previous population-based studies have been performed over a longer, continuous time period. In residents younger than 35 years, Khosla et al. reported a slight decrease between the periods 1989-1991 to 1999-2001 in boys and girls.[16] A study from Finland reported an increased incidence rate of distal forearm fractures in children and adolescents treated in hospital in the period 1996-2006.[10]

The relatively strong increase of wrist fractures due to sports in childhood deserves further attention. This increase might be explained by changing sport- and leisure time activities, for example by an increase in participation in sporting or recreational activities. The greater number of male youth soccer players compared to female players in the Netherlands may explain why the number of soccer-related fractures in boys is much greater than in girls.[6] Khosla et al. described a small increase in wrist fractures associated with skiing and skating among boys, and with basketball, soccer, and skating among girls in the US.[16] This shows that increases in sports participation may be accompanied by higher injury occurrences. Conversely, a case-control study has reported that television, computer, and video viewing have a dose-dependent association with wrist and forearm fractures, whereas light physical activity is protective.[4]

The main strength of our study is that we present population-based data on the incidence of wrist fractures over a long, continuous time-period. Previous studies have mainly focused on a small number of hospitals and were limited to either hospitalized patients or non-hospitalized patients. In this study, we included both nationwide data on hospitalized patients and data from a representative national sample of non-hospitalised patients. Although only 12% of the total Dutch population is represented in the sample, international validation studies have shown that the Dutch Injury Surveillance System has a high level of completeness and validity.[18,24] The participating hospitals in this database are geographically scattered over the country. This diminishes possible selection biases stemming from differences between rural and urban areas.[26-28] Another strength of our study is that fractures we analysed are part of the selected radiological verifiable fractures. These fracture types have been recommended for comparative research and trend analyses by international expert groups because in the vast majority of cases these patients will seek care in the emergency department and the fractures will be detected by X-rays.[29]

One of the limitations of a population-based registry of this scale is the lack of available information on the precise location and type the fracture and whether the fracture was open or closed. This is due to the use of non-specific fracture codes, such as wrist fracture, which includes both distal radius and carpal fractures. Therefore the precise distribution between distal radius fractures and carpal fractures in this study is not known. From previous studies, we know that carpal fractures are rare in the pediatric population.[30,31] In a study on children aged 0 to 16 years, 33% of all fractures were distal forearm fractures, while only 1% were scaphoid fractures.[2] However, the incidence of scaphoid fracture diagnosis may have increased, for example by the use of magnetic resonance imaging or computed tomography that can confirm a scaphoid fracture at an earlier stage compared to plain radiographs.[32] This is a limitation of our study since in the majority of clinically suspected fractures X-rays were made in an emergency department and the number of true scaphoid fractures could not be verified from the injury surveillance system afterwards. Another limitation is that patients were selected based on the registered primary diagnosis. In the case of multiple injuries, the most severe injury was registered in the injury surveillance system. This means that cases of wrist fractures combined with a more severe injury (e.g. intracranial injury) have not been included in the analyses, which may lead to an underestimation of the true incidence.

Our population-based study revealed a marked increase of the incidence rate of sports-related childhood wrist fractures from 1997 through 2009, mainly related to soccer and school gymnastics. From the present literature, it is not clear what mechanisms led to the increase due to sports. Since our study shows a relatively strong increase in wrist fracture incidence and since the popularity of soccer continues to be high,[33] studying the specific causes of soccer-related wrist fractures and devising preventive measures may be important.[34,35] After adjustment for potential increases in sports participation, the role of modifiable risk factors in soccer and school gymnastics should be investigated. This may lead to strategies that can reverse the unfavourable trends in pediatric wrist fractures and thus improve public health.

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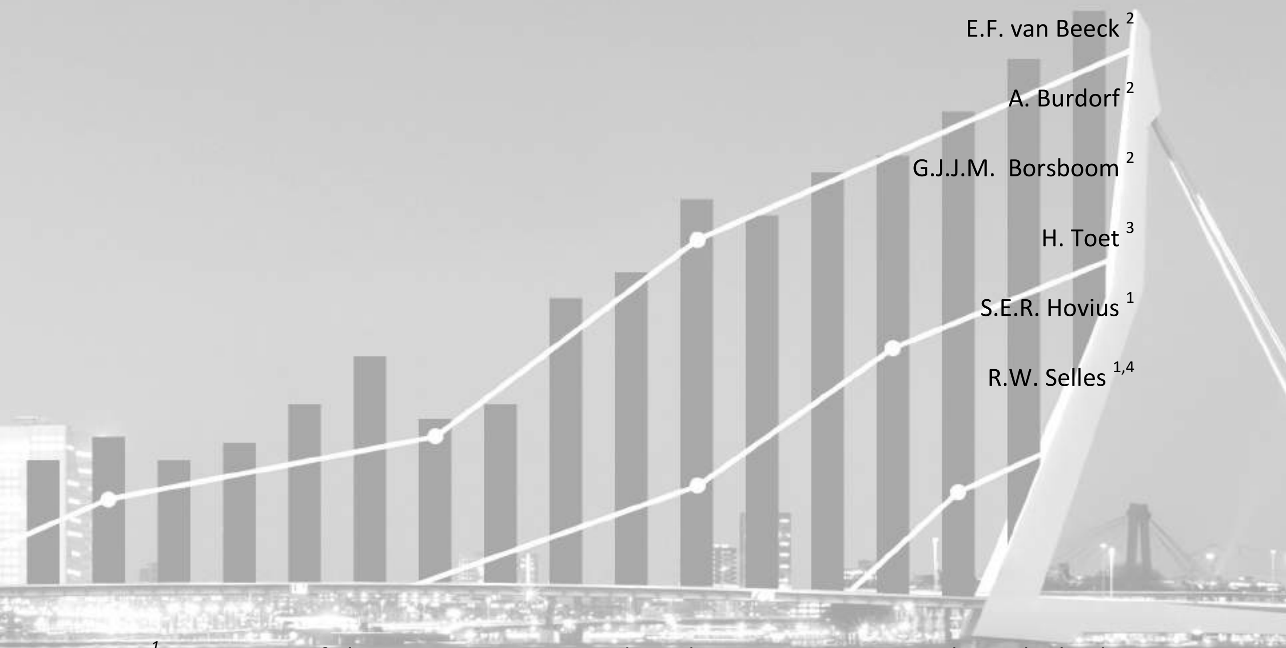
Chapter 3

Increase in Upper Extremity Fractures in Young Male Soccer Players in the Netherlands, 1998-2009



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ABSTRACT

Purpose

Young male soccer players have been identified as a target group for injury prevention, but studies addressing trends and determinants of injuries within this group are scarce. The goal of this study was to analyse age-specific trends in hospital-treated upper extremity fractures (UEF) among boys playing soccer in the Netherlands and to explore associated soccer-related factors.

Methods

Data were obtained from a national database for the period 1998-2009. Rates were expressed as the annual number of UEF per 1000 soccer players. Poisson's regression was used to explore the association of UEF with the number of artificial turf fields and the number of injuries by physical contact.

Results

UEF rates increased significantly by 19.4% in boys 5-10 years, 73.2% in boys 11-14 years and 38.8% in boys 15-18 years old. The number of injuries by physical contact showed a significant univariate association with UEF in boys 15-18 years old. The number of artificial turf fields showed a significant univariate association with UEF in all age groups, and remained significant for boys aged 15-18 years in a multivariate model.

Conclusions

This study showed an increase of UEF rates in boys playing soccer, and an independent association between artificial turf fields and UEF in the oldest boys.

INTRODUCTION

Sports participation is important to improve fitness and activity levels in childhood, but may also lead to injuries.[1-3] This in particular concerns contact sports, such as soccer, the most popular team sport worldwide with increasing popularity in childhood.[4] The majority of soccer-related injuries in childhood that are treated at a hospital concern the upper extremity and affect boys.[3,5]

It has been recognized that injury prevention should target young male soccer players, but epidemiological studies addressing trends and determinants of injuries within this group are scarce.[6] Therefore, risk factors are largely unknown, although the contribution of several soccer-related factors has been hypothesized.[7-13] These include increases in physical contact and foul play as well as playing on artificial turf, although the latter remains controversial.[14-18]

We conducted an epidemiological study to examine age-specific trends in upper extremity fractures among boys (5-18 years old) playing soccer in the Netherlands, and to explore associations of soccer-related factors with these trends.

PATIENTS AND METHODS

Data sources

We examined the incidence of upper extremity fractures (UEF) during soccer in organized play, among male players aged 5-18 years, in the Netherlands, from 1998 to 2009. Data were obtained from the Dutch Injury Surveillance System for non-hospitalized patients and the National Hospital Discharge Registry for hospitalized patients.[19-21] In the Dutch Injury Surveillance System, all injuries treated at the emergency department (ED) are recorded. Fifteen hospitals participated in this injury surveillance system during the complete study period, including 3 university hospitals and 12 general hospitals. The geographically-separated hospitals were selected to draw from both rural and urban areas and form a sample of 12% of the total number of injury patients presenting at the EDs in the Netherlands (population of 16.5 million in 2009). The patients attending these hospitals are representative of the Dutch population in terms of age and sex, and extrapolations can be made to the national level.[19,22] In the National Hospital Discharge Registry, individual information on inpatient care is collected on a nationwide basis with almost 100% coverage.

Injury diagnoses are registered by using the International Classification of Diseases of the World Health Organization (ICD 10th revision). We included all male patients, aged 5-18 years, with fractures to the upper extremity (S42.0-9, S52.0-9 and S62.0-9 of the ICD 10th revision). Fracture registration was conducted by the hospital physicians. Registered data include the patient’s name, age, and information on diagnosis, treatment and discharge. The injury was classified based on the registered primary diagnosis, according to the Eurocost classification of diagnostic groups as developed and recommended by European experts.[19,20] In case of multiple injuries, the primary injury was determined by application of an algorithm giving priority to spinal cord injury and skull/brain injury above injuries in other body parts, and to fractures above other types of injury.[20] Causes of injury were routinely recorded according to the International Classification of External Causes of Injuries (ICECI), which has been developed for injury prevention. In this classification, the cause of injury is classified, e.g. sports-related injuries. The ICECI is complementary with the external cause codes (Chapter XX) of the ICD-10, and provides more detailed information on the cause of injury, with soccer in organised play as one of the subcategories in sports.[23] Within this subcategory of injuries, a subdivision could be made between injuries due to physical contact and non-contact-related injuries. The proportion of injuries due to physical contact was interpreted as an indicator for foul play.[10,24] Exposure data on the annual number of soccer players in the age groups 5-10, 11-14 and 15-18 years and the annual number of artificial turf fields were obtained from the Royal Netherlands Football Association.[25]

Statistical Analysis

Fracture rates were expressed as the number of UEF per 1000 male youth soccer players per year, based on the number of soccer participants for each study year between 1998 and 2009. Poisson regression was used to investigate the trend in the number of UEF over time by including the year in which the measurements were made as a linear term in the model. Subsequently, the effect of the number of artificial turf fields and the proportion of injuries caused by physical contact were examined by also including these variables as linear terms in the model. The logarithm of the number of soccer players in the Netherlands was used as an offset variable. Confidence intervals of 95% (95% CI) for the rates were calculated and a p-value < 0.05 was considered statistically significant. Models were fitted with the GENMOD procedure in SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Ethical committee approval is not required for register-based studies in The Netherlands.

RESULTS

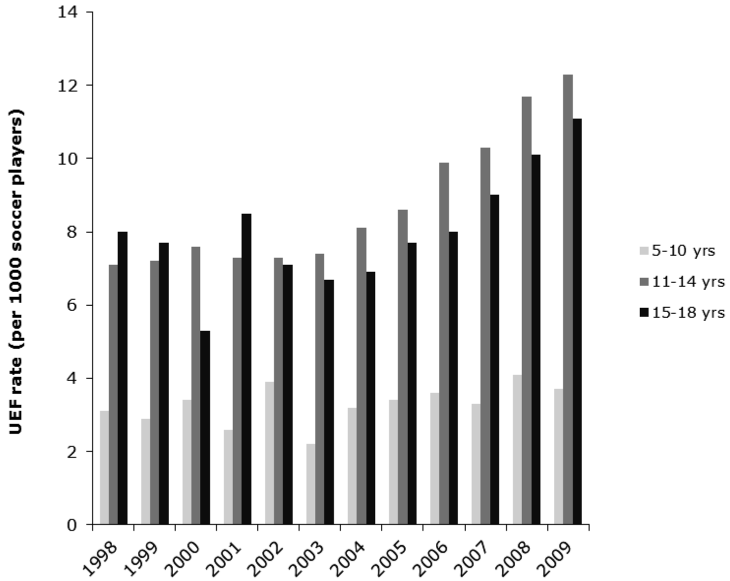
During the study period from 1998 to 2009, approximately 168,000 male soccer players aged 5-18 years were treated at the ED for injuries due to soccer in organized play. The majority of these injuries (47.4%) affected the upper extremity and wrist fracture was the most common injury type (Table 1). The absolute number of UEF (in thousands) increased from 2.4 in 1998 to 4.4 in 2009, representing a 83.6% increase. The number of male soccer participants aged 5-18 years increased from 417 540 to 531 008 in the same period, representing a 22.7% increase.

Table 1 Number of upper extremity fractures (UEF) in male soccer players aged 5-18 years (in the Netherlands, 1998-2009)

	Absolute number (%)
Shoulder	5602 (14%)
Upper arm	849 (2%)
Elbow	1618 (4%)
Forearm	4265 (11%)
Wrist	16 151 (41%)
Hand/finger	10 920 (28%)
Total UEF	39 405 (100%)

Combining fracture rate and participation, we found that in boys aged 5-10 years (Figure 1), the number of UEF per 1000 soccer participants increased by 19.4% from 3.1 [95% CI, 2.8-3.3] in 1998 to 3.7 [3.5-4.0] in 2009 (p=.014). In boys aged 11-14 years, fracture rates per 1000 soccer players increased by 73.2%, from 7.1 [6.7-7.5] in 1998 to 12.3 [11.8-12.8] in 2009 (p<.0001). In the oldest age group, 15-18 year-old boys, fracture rates per 1000 soccer players increased by 38.8% from 8.0 [7.5-8.6] to 11.1 [10.5-11.7] (p<.0001). The number of artificial turf fields increased exponentially from 17 in 2001, to 962 in 2009. The number of injuries (in thousands) caused by physical contact increased from 3.8 in 1998 to 4.4 in 2009.

Figure 1 Upper extremity fracture (UEF) rates per 1000 male soccer players aged 5-10, 11-14 and 15-18 years (in the Netherlands, 1998-2009)



The number of injuries caused by physical contact showed a univariate significant association with increasing fracture rates in boys 15-18 years old, but not in other age groups nor in multivariate analysis (Table 2). The number of artificial turf fields showed a univariate significant association with increasing fracture rates in all age groups. This variable remained significant for boys 15-18 years old, after adjustment for contact-related injuries in the multivariate analysis (p=0.002).

Table 2 Univariate and multivariate hazard ratios of upper extremity fractures by artificial turf and contact-related injuries, in male soccer players

	Univariate Hazard ratio (95% CI)	p-value	Multivariate hazard ratio (95% CI)	p-value
5-10 years				
Artifical turf fields	1.027 (1.007-1.048)	0.008	1.023 (0.965-1.083)	0.446
Contact injuries	1.002 (0.996-1.008)	0.486	1.001 (0.993-1.008)	0.892
11-14 years				
Artificial turf fields	1.062 (1.048-1.076)	<0.001	1.032 (0.990-1.076)	0.137
Contact injuries	1.002(1.000-1.004)	0.092	1.002 (0.999-1.004)	0.235
15-18 years				
Artificial turf fields	1.049 (1.031-1.067)	<0.001	1.076 (1.029-1.126)	0.002
Contact injuries	1.002 (1.001-1.004)	0.006	1.000 (0.998-1.002)	0.847

DISCUSSION

This study showed a significant increase the number of UEF per 1000 young male soccer players during the period 1998-2009. We studied the influence of two soccer-related factors: physical contact versus playing on artificial turf fields. We found no consistent nor independent effect of physical contact on UEF among young male soccer players, but found some support for the hypothesis that playing on artificial grass could be harmful. The increase in fracture rate in the age group 15-18 years was associated with an increase of playing on artificial turf, after adjustment for physical contact injuries.

This result is in line with a study of Lawson et al., who calculated a fivefold increase in the risk of sustaining a wrist fracture falling on synthetic turf compared to natural grass.[26] Nevertheless, the effect of artificial turf on soccer-related injuries is still controversial due to inconsistent results from previous cohort studies addressing the injury risk during soccer played on artificial turf fields and on natural grass.[14-18] A prospective cohort study with a two year follow-up among American soccer players at college and university showed similar upper limb injury rates (number of injuries during 1000 hours of exposure) for artificial turf and natural grass among both men and women. However, incidence rates of mild and moderate injuries (defined as 4-28 days missed from training) were higher on artificial turf than on grass for men.[17] A prospective cohort study among male European elite soccer players found no evidence for greater injury risk on artificial turf compared with natural grass; Only a higher incidence of ankle sprains was observed, but the number of ankle sprains in this study was small.[16] A prospective cohort study from Norway showed a trend towards more ankle sprains among young female soccer players playing on artificial turf, while the rate ratio of upper limb injuries was similar between artificial turf and natural grass. During matches, however, the incidence of serious injuries (defined as missed more than 21 days) was higher on artificial turf.[18] A case-control study from Japan on adolescents aged 12-17 years showed no significant difference in incidence rate of acute injuries between natural grass and artificial turf.[15] Play behaviour, such as seeking physical contact and/or foul play, has been suggested as another contributing factor for increasing injury rates. It can be derived from previous studies that foul play is associated with a significant number of contact-related injuries.[9,10,24] In our study, however, no consistent nor independent effect of physical contact could be demonstrated.

The main strength of our study is that we present population-based data on trends of upper extremity fractures over a long, continuous time-period. This study covers a twelve-year period, including different seasons, and uses the same injury definitions and methods over time. Previous studies have mainly focused on a small number of hospitals and were limited to either inpatients or outpatients. In this study we included both nationwide data on inpatients and data from a representative national sample of outpatients. Although only 12% of the total Dutch population is represented in the sample, international validation studies have shown that the Dutch Injury Surveillance System has a high level of completeness and validity.[19,22] The participating hospitals in this database are geographically scattered over the country, to avoid selection biases stemming from differences between rural and urban areas.[27] Another strength of our study is that fractures we analysed are part of the selected radiological verifiable fractures. These fracture types have been recommended for comparative research and trend analyses by international expert groups because in the vast majority of cases these patients will seek care in the ED and the fractures will be detected by x-rays.[28]

Several limitations of our study have to be addressed. First of all, although we observed an increase in hospital-treated UEF among young male soccer players in the period 1998-2009 that coincides with an increase in the absolute number of artificial turf fields in the Netherlands, this association does not allow causal inference.[29] Secondly, we expressed fracture rates per 1000 youth soccer players, to adjust for the population at risk. Most previous studies expressed injury rates per 1000 hours exposure. However, for the whole study-period it was not possible to obtain population-based data on the hours of soccer participation. Since a previous study on sports participation among young athletes aged 0-19 years showed a slight decrease in the average hours of sports participation per week, from 3.5 in the period 1997-1998 to 3.0 in 2000-2002, it seems less likely that the increase in the number of injuries resulted from an increase in exposure hours.[30] Thirdly, only a limited number of variables could be included in our study due to lack of adequate data on several parameters of potential relevance. Overweight, for example, might be a risk factor for compromised bone health in childhood, although the influence of overweight on bone during critical stages of bone growth remains uncertain.[31-34] In addition, international studies suggest a negative association between overweight and performance on neuromotor fitness tests.[12,35] Runhaar et al. observed a decrease in neuromotor fitness in Dutch youth aged 9-12 years over the period 1980-2006. In the Netherlands, the prevalence of overweight in boys aged 5-18 years increased in all age groups in the period 1997 to 2009, from 10.3% to 13.6% in boys aged 5-10 years, from 7.2% to 12.1% in boys aged 11 to 14 years and from 8.2% to 13.5% in the oldest age group.[36] This development in overweight and related motor skills could contribute to the observed rise in soccer-related UEF, but this parameter was not included in our analyses since annual data are lacking.

In conclusion, this study showed an increase of UEF rates per 1000 young male soccer players of all ages. For the oldest category, 15-18 years, an independent association between artificial turf fields and UEF could be demonstrated. The hypothesis that playing on artificial grass could be harmful should not be abandoned.

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Chapter 4

Epidemiology and Health Care Utilization of Wrist Fractures in Older Adults, 1997-2009

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ABSTRACT

Purpose

Wrist fractures are common older adults and are expected to increase because of ageing populations worldwide. The introduction of plate and screw fixation has changed the management of this trauma in many patients. For policy making it is essential to gain insight into trends in epidemiology and healthcare utilization**.** The purpose of this study was to determine trends in incidence, hospitalization and operative treatment of wrist fractures.

Methods

Population-based study of patients of 50 years and older using the Dutch National Injury Surveillance System and the National Hospital Discharge Registry. Data on emergency department visits, hospitalizations and operative treatment for wrist fractures within the period 1997-2009 were analysed.

Results

In females, the age-standardized incidence rate of wrist fractures decreased from 497.2 per 100,000 persons (95%CI, 472.3-522.1) in 1997 to 445.1 (422.8-467.4) in 2009 (*P* for trend <.001). In males, no significant trends were observed in the same time period. Hospitalization rates increased from 30.1 (28.3-31.9) in 1997 to 78.9 (75.1-82.8) in 2009 in females (*P*<.001), and from 6.4 (6.0-6.8) to 18.4 (17.3-19.5) in males (*P*<.001). There was a strong increase in operative treatment of distal radius fractures, especially due to plate fixation techniques in all age-groups.

Conclusions

Incidence rates of wrist fractures decreased in females and remained stable in males, but hospitalization rates strongly increased due to a steep rise in operative treatments. The use of plate and screw fixation techniques for distal radius fractures increased in all age groups.

INTRODUCTION

Wrist fractures are one of the most common fractures and result in high numbers of emergency department (ED) visits and related healthcare costs, especially among the older population.[1-3] With ageing populations worldwide and an increasing life expectancy, the absolute number of fractures and related healthcare demand are expected to increase.[4-6]

Previous studies on the epidemiology of distal forearm fractures have shown geographical variation in incidence, with higher rates in North America and Europe compared with Asia.[7-16] However, most of these studies were limited to one or a few clinics,[8] compared only two or three time points to analyze trends,[9,10] or included either non-hospitalized or hospitalized patients.[11,12] Recent studies from the US showed a shift from conservative treatment towards internal fixation in the management of this trauma, but these studies were based on a sample of insurance data and did not cover the whole US population.[17-19]

For policymaking it is essential to gain insight into trends in the epidemiology and healthcare utilisation of wrist fractures. This information is essential for the allocation of healthcare in the future, but has so far largely been absent. The purpose of this nationwide study was to examine trends in age- and gender-adjusted incidences, hospitalisation and operative treatment of wrist fractures in the full population of older adults (ages 50 and older) in the Netherlands.

METHODS

Data sources

The incidence and hospitalization rates of wrist fractures among the Dutch population aged 50 years and older were analysed from 1997 throughout 2009. Using the International Classification of Diseases of the World Health Organization (ICD, 10th revision), a wrist fracture was defined as a distal radius fracture (S52.5), combined fracture of the distal radius and ulna (S52.6) or a carpal fracture (S62.0 and S62.1). Injury cases were obtained from the Dutch Injury Surveillance System for non-hospitalized patients and the Hospital Discharge Registry for hospitalized patients.[6,20,21]

In the Dutch Injury Surveillance System, all unintentional and intentional injuries treated at the ED are recorded, and methods comparable with previous studies are applied.[6,22,23] Fifteen hospitals participated in this injury surveillance system during the study period, including 3 university hospitals and 12 general hospitals. These geographically-separated hospitals were selected to draw from both rural and urban areas and form a representative sample of 12% of the total number of injury patients presenting at the EDs in the Netherlands (population of 16.5 million inhabitants in 2009). The people using these participating hospitals are representative for the Dutch population in age and gender. In this way, extrapolations can be made to national level.[6,20,24]

The Hospital Discharge Registry uses a uniform classification and coding system, and has nationwide more than 95% coverage.[21] Data regarding gender, age, hospital admissions, admission diagnosis, length of hospital stay and trauma mechanism are stored in this data system. Patients were selected based on the registered primary diagnosis, according to the diagnostic groups as previously recommended by European experts.[24,25] All patients aged 50 years and older with a primary diagnosis of a wrist fracture were included, and fracture registration was conducted by the treating physician in each hospital.

For the period 2004-2009, we were able to obtain data on the operative treatment of distal radius fractures, and to analyse trends per age group. The Hospital Discharge Registry was searched for the ICD-10 code indicating a distal radius fracture

(S52.5), the most frequent surgically treated wrist fracture. For this group of fractures, the corresponding procedure codes were retrieved: percutaneous fixation (5-790), open reduction without internal fixation (5-791), and open reduction with internal fixation (5-792). Within the last group, two different fixation methods could be identified: Kirschner-wire fixation (5-792.03) and plate and screw fixation (5-790.13). Ethical committee approval is not required for register-based studies in the Netherlands. The Institutional Review Board approved the study methods (MEC-2010-402).

Statistical Analyses

Patients were divided into gender- and age-specific ten-year age groups (50-59, 60-69, 70-79 and 80 years and older). The age- and gender-specific incidence rates were expressed per 100,000 persons, based on the Dutch mid-year population for each study year between 1997 and 2009. The mid-year population sizes for each age group were obtained from Statistics Netherlands. Direct standardization was used to calculate age-standardised incidence rates, and a Poisson's regression analysis was used to analyse changes over time. Confidence intervals of 95% (CI 95%) for the rates were calculated. A *p*-value less than .05 was considered as statistically significant.

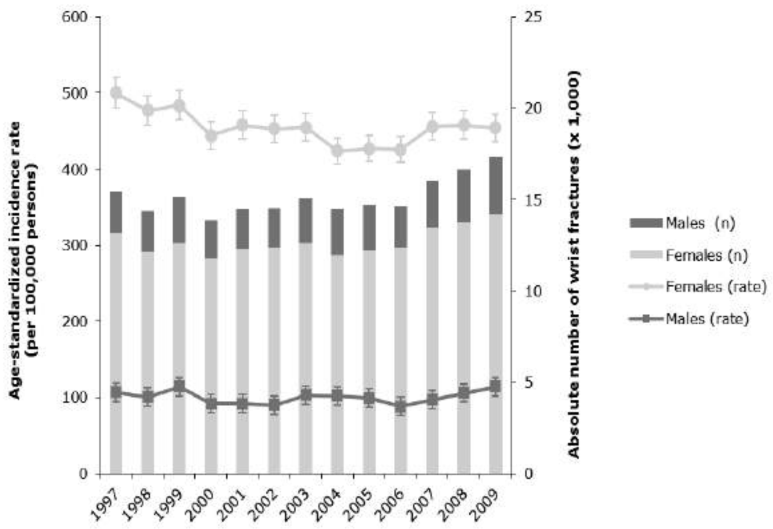
RESULTS

Fracture incidence rates and trends

During the study-period from 1997 to 2009, approximately 196,700 patients (83.9% females) of 50 years and older were diagnosed with a wrist fracture. The absolute number of wrist fractures in patients aged 50 years and older increased from 15,439 in 1997 to 17,343 in 2009. Between 1997 and 2009, the annual mean number of wrist fractures for females was 457.8 per 100,000 (95% CI, 434.9 to 480.7) and 100.4 per 100,000 persons (95% CI, 95.4 to 105.1) for males.

Overall, in females, age-standardized incidence rates decreased from 1997 to 2009 and remained stable in males (Figure 1). In females, age-standardized wrist fracture rates decreased from 497.2 (95% CI, 472.3 to 522.1) in 1997 to 445.1 (95% CI, 422.8 to 467.4) in 2009 (*P* for trend <.001). In male, rates did not change significantly, from 111.2 (95% CI, 105.6 to 116.8) to 118.5 (95% CI, 112.6 to 124.4) in the same time period (*P*=.84). In both males and females, the highest incidence rates were found in the oldest age group (Table 1).

Figure 1 Absolute number of wrist fractures and age-standardized incidence rates in males and females aged 50 years and older in the Netherlands. Error bars indicate 95% confidence intervals.



Age-specific rates decreased in the age-groups 60-69 years ($P<.001$) and 70-79 years ($P=.04$) for females, while there were no significant changes in the other age-groups. Among males, age-specific rates were stable in age-groups 50-59, 60-69 and 70-79 years. The highest age-specific rates occurred in males aged 80 years and older, showing a slightly decreasing trend over time ($P=.06$).

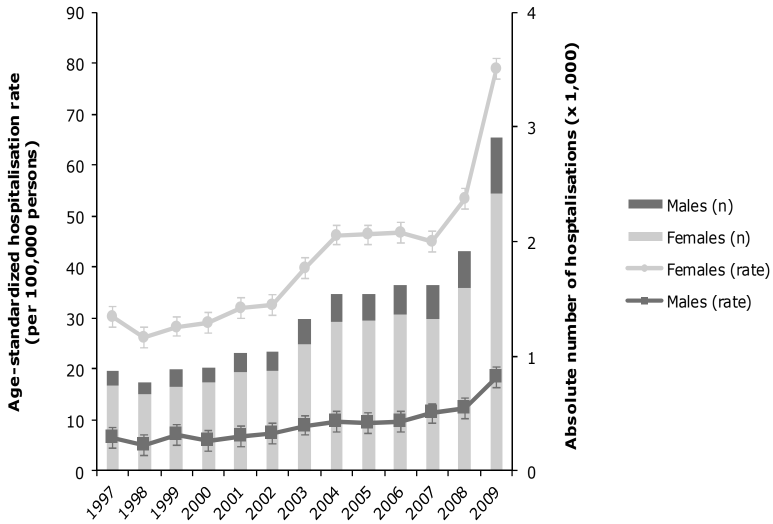
Table 1 Age- and gender-specific wrist fracture incidence rates in males and females aged 50 years and older in the Netherlands and relative changes in the period 1997-2009.

Age group, y	**1997**	**1999**	**2001**	**2003**	**2005**	**2007**	**2009**	
				Incidence rates (per 100,000 persons)				Relative change, %
				Females				
50-59	266.1	254.8	229.4	233.4	222.4	257.4	278.2	4.5
60-69	517.4	442.6	456.2	408.2	397.7	422.5	422.0	-18.4
70-79	664.7	655.6	675.6	636.8	596.1	640.5	631.4	-5.0
≥80	828.3	777.6	744.6	783.9	803.3	799.4	809.3	-2.3
				Males				
50-59	96.4	90.8	85.0	96.1	89.1	94.8	108.2	12.2
60-69	91.0	89.7	81.1	89.3	91.3	90.3	116.3	27.8
70-79	117.8	109.3	94.5	109.3	86.2	110.3	115.0	-2.4
≥80	173.3	223.2	167.0	185.0	147.2	164.9	142.6	-17.7

Trends in hospitalization and operative treatment

The absolute number of hospitalizations due to wrist fractures in patients aged 50 years and older increased from 877 in 1997 to 2,912 in 2009 (Figure 2). In females, the majority of hospitalizations occurred in the age-group 60-69 years, and rose from 236 to 812 between 1997 and 2009. In males, the majority of hospitalizations occurred in the age-group 50-59 years, and increased from 83 in 1997, to 226 in 2009.

Figure 2 Absolute number of hospitalizations and age-standardized rates due to wrist fractures in males and females aged 50 years and older in the Netherlands. Error bars indicate 95% confidence intervals.



In females, age-standardized hospitalization rates increased from 30.1 (95% CI, 28.3 to 31.9) in 1997, to 78.9 (95% CI, 75.1 to 82.8) in 2009 (*P*<.001). In males, an increase was seen from 6.4 (95% CI, 6.0 to 6.8) to 18.4 (95% CI, 17.3 to 19.5) in the same time period (*P*<.001). Significant increases in hospitalization rates were observed within each age-group, in both males and females (all *P*-for trend <.001). The strongest increase was observed in 50-59 year old females, and in 60-69 years old males (Table 2).

Table 2 Age- and gender-specific hospitalization rates due to wrist fractures in males and females aged 50 years and older in the Netherlands and relative changes in the period 1997-2009.

Age group, y	1997	1999	2001	2003	2005	2007	2009	
	Hospitalization rates (per 100,000 persons)							Relative change, %
	Females							
50-59	17.4	15.1	19.7	23.1	25.0	23.4	53.1	205.1
60-69	33.8	30.1	38.0	41.8	51.1	46.2	88.7	162.4
70-79	42.8	48.6	46.7	65.4	68.5	64.1	96.9	126.4
≥80	33.4	24.1	29.8	36.4	62.8	62.5	97.1	190.7
	Males							
50-59	8.8	8.4	9.0	10.6	10.8	13.0	19.9	126.1
60-69	5.3	7.1	5.9	10.2	8.6	10.6	20.6	288.7
70-79	4.5	4.8	4.7	5.0	7.9	7.6	15.2	200.0
≥80	4.4	5.8	3.7	4.5	3.6	4.8	8.3	88.6

In the population of 50 years and older, the absolute number of operative procedures increased from 1,163 in 2004 to 1,813 in 2009, mainly due to an increase in operative treatment in the age-groups 50-59 and 60-69 years (Figure 3). A strong increase in the use of plate and screw fixation techniques was observed among all age groups (Table 3), while the number of other procedures remained stable in this period (data not shown).

Figure 3 Absolute number of operative procedures for distal radius fractures in males and females aged 50 years and older in the Netherlands, by age group and year (2004-2009).

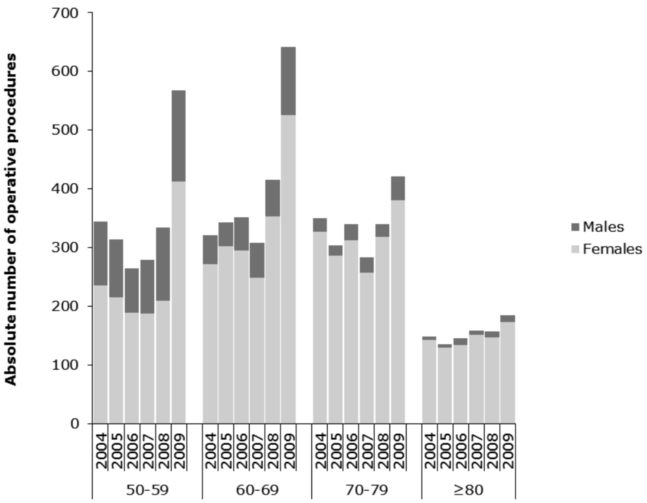


Table 3: Absolute number of plate and screw fixations for treatment of distal radius fractures in males and females aged 50 years and older in the Netherlands and the relative changes in the period 2004-2009.

Age Group, y		**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	
	Procedure			**Absolute number of procedures (N, %)**				Relative change, %
50-59	Plate and screw fixation	132 (38)	139 (44)	137 (52)	160 (57)	205 (61)	360 (63)	172.7
	Other	212 (62)	174 (56)	127 (48)	119 (43)	129 (39)	207 (37)	-2.4
60-69	Plate and screw fixation	120 (37)	129 (38)	150 (43)	164 (53)	248 (60)	418 (65)	248.3
	Other	201 (63)	214 (62)	201 (57)	144 (47)	167 (40)	223 (35)	-10.9
70-79	Plate and screw fixation	111 (32)	86 (28)	143 (42)	125 (44)	181 (53)	220 (52)	98.2
	Other	239 (68)	217 (72)	197 (58)	159 (56)	159 (47)	201 (48)	-15.9
≥80	Plate and screw fixation	27 (18)	29 (21)	49 (34)	57 (36)	67 (43)	71 (39)	163.0
	Other	121 (81)	106 (79)	96 (66)	102 (64)	90 (57)	113 (61)	-6.6

DISCUSSION

This study reports significant changes in the patterns of hospitalization rates and surgical management of wrist fractures in the Netherlands over a 13-year period. During the study period, incidence rates of wrist fractures decreased significantly in females, and remained relatively stable in males. In contrast, hospitalization rates increased roughly threefold in both females and males, and among all age groups. The increase in hospitalization was due to a shift in treatment from conservative treatment by cast immobilisation towards operative treatment and internal fixation of distal radius fractures, especially due to plate and screw fixation techniques.

The main strength of the current study is that we use population-based data on the incidence and hospitalization of wrist fractures collected over a longer, continuous time-period. Previous studies have mainly focused on a small number of hospitals and were limited to either non-hospitalized or hospitalized patients. In this study, nationwide data on both hospitalized patients and data from a representative national sample of non-hospitalized patients were used. International validation studies have shown that the Dutch Injury Surveillance System has a high level of completeness and validity.[24,25] The participating hospitals in this injury surveillance system are geographically divided over the country, to avoid selection biases stemming from differences between rural and urban areas.[26] For hospitalized patients, previous studies have shown that the Hospital Discharge Registry is accurate and has an excellent coverage.[24,25]

One of the limitations of a population-based registry of this scale is the lack of available information on the precise anatomic location of the fracture, fracture type, or whether the fracture was open or closed. This is due to the use of non-specific fracture codes, such as wrist fracture in the Dutch Injury Surveillance System, which includes both distal radius fractures and fractures of the carpal bones. In the hospital discharge registry distinction between ICD-10 codes could be made, while in the injury surveillance system these injuries were grouped together as ‘wrist fractures’. Therefore the precise distribution between distal radius fractures and carpal fractures in the injury surveillance system is not known. Another limitation is that patients were selected based on the registered primary diagnosis. In case of multiple injuries, the most severe injury was registered in the injury surveillance system. This means that patients with wrist fractures combined with a more severe injury (e.g. intracranial injury) have not been included in the analyses, and that the true incidence of wrist fracture rates is underestimated.

Similar decreasing trends in the incidence of wrist fractures have been reported in other countries, including from earlier periods in the United States and Canada. Melton et al. reported decreasing wrist fracture rates from 1975 to 1994 in a population-based study performed in Minnesota in patients aged 35 years and older.[14] More recently, Jaglal et al. reported stable wrist fracture incidence rates between 1992 and 1996 and a decreasing rate in the elderly patients (aged 50 years and older) in the Canadian population between 1997 and 2000.[15] The mechanisms of the decreasing wrist fracture incidence rates are still unknown. However, a similar trend was observed for hip fractures worldwide.[27,28] Similar factors which have been reported to contribute to the recent decrease in hip fractures may also contribute to a decrease in wrist fractures. For example, hormone replacement therapy has been shown to increase bone mineral density and to reduce hip fracture incidence.[29-31] In addition, obesity is increasing in Western societies and may be associated with a reduced fracture risk in older adults. However, the relationship between fat mass and bone density varies with age, and more detailed imaging techniques are needed to clarify the relation between fat and bone with increasing age.[32] Smoking has also been associated with an increased risk of fracture[33] however, declining smoking rates alone can not explain stable fracture rates in males in this study.

Trends in wrist fracture hospitalization rates have been described in a few previous studies, varying from a decreasing rate in France, to increasing rates in Australia and Switzerland. Maravic et al. reported a decreasing rate from 2002 to 2006, while the absolute number of hospitalizations increased as a consequence of aging.[11] Boufous et al. showed a gradual increasing rate in both males and females in the period 1993-2003,[12] while Lippuner et al. reported an increasing number and incidence of hospitalizations for wrist fractures for 2000-2007.[13] A possible explanation for increasing hospitalization rates might be changes in surgical policies for operative treatment of distal radius fractures.[9] Studies from the United States and Finland on trends in treatment of distal radius fractures showed a trend towards more operative fixation of distal radial fractures.[17-19,34] Chung et al. suggested that the rapid increase in the use of internal fixation corresponded with the earliest report on the volar locking plating system, which was published in 2000. In the Dutch guidelines for the treatment of distal radial fracture surgical treatment is advised in inadequately reduced fractures in patients below the age of 65 years. Above 65 years a more reserved indication for operative treatment is suggested. This is, to our knowledge, the first population-based study to show stable (males) and decreasing (females) incidence rates, combined with a threefold increase in hospitalization rates within 13 years, and a rapidly rising application of plate and screw fixation techniques in older persons with wrist fractures.

Injury surveillance is necessary to monitor trends in incidence of wrist fractures. Several studies showed an increasing trend from conservative treatment by cast immobilisation, towards operative treatment and internal fixation. However, a systematic review by Diaz-Garcia et al. suggests that despite worse radiographic outcomes associated with conservative treatment by cast immobilization, functional outcome was no different from surgically treated patients aged 60 and over.[35] In patients older than 64 years, nonoperative treatment may be preferred because of lower disutility from malunion and painful malunion outcome states.[36] In addition, current guidelines from the American Academy of Orthopaedic Surgeons (AAOS) for treatment of distal radius fractures in patients of 55 years and older do not recommend for or against operative treatment [37-40] or locking plates.[41]

The trend towards operative treatment and volar plate fixation results in increased healthcare cost. A cost analysis study by Shyamalan et al. reported material costs of two Kirschner-wires to be around US $1.25, compared with US $914 including a volar locked plate (US $768), distal plate screws (US $92) and proximal plate screws (US $54). In addition, applying a volar locking plate took 216% longer time than using two Kirschner-wires.[42] Shauver et al. reported costs due to distal radius fractures to be US $140 million in 2007, and that the burden of distal radius fractures will be growing as the US population ages and as internal fixation becomes more widely used.[5] Because of the rising healthcare expenditures, it is important to provide cost-effective care without compromising functional outcome or patient safety. Therefore, there is a need for good quality evidence for the surgical management of distal radius fractures in older adults compared to cast immobilisation, including long term outcome, complications and cost-effectiveness.

In conclusion, this study showed decreasing incidence rates of wrist fractures in females and stable rates in males. The threefold increase in hospitalization was mainly driven by an increasing trend in operative treatment of distal radius fractures. The use of plate and screw fixation techniques increased in all age-groups, despite insufficient evidence from randomised controlled trials. There is a need for high quality evidence on the surgical management of distal radius fractures in older adults compared to cast immobilisation, including long term outcome, complications and cost-effectiveness.

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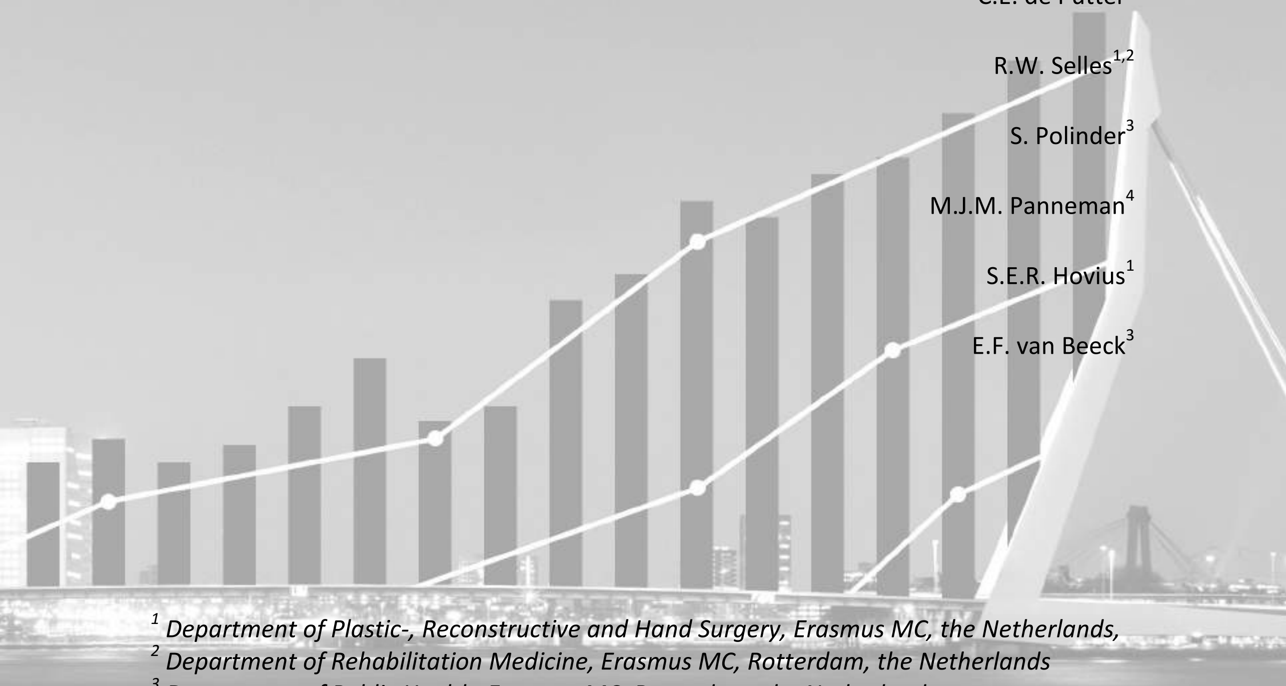
PART II

Societal Consequences

Chapter 5

Economic Impact of Hand and Wrist Injuries in The Netherlands

Healthcare Costs and Productivity Costs in a Population-based Study



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ABSTRACT

Purpose

Hand and wrist injuries account for approximately twenty percent of the attendances at the ED and may impose a large economic burden. The purpose of this study was to estimate the total healthcare costs and productivity costs of injuries to the hand and wrist and to compare them to other important injury groups in a nationwide study.

Methods

Data were retrieved from the Dutch Injury Surveillance System, from the National Hospital Discharge Registry and from a patient follow-up survey conducted between 2003 and 2007. Injury incidence, healthcare costs, and productivity costs (due to absenteeism) were calculated by age-category, gender and different subgroups of injuries. An incidence-based cost model was used to estimate healthcare costs of injuries. Follow-up data on return to work rates were incorporated in the absenteeism model for estimating the productivity costs.

Results

Hand and wrist injuries annually account for US $740 million and rank first in the order of most expensive injury types, before knee- and lower leg fractures (US $562 million), hip fractures (US $532 million) and skull-brain injury (US $355 million). Productivity costs contributed more (56%) than direct healthcare costs to the total costs of hand and wrist injuries. Within the overall group of hand and wrist injuries, hand and finger fractures are the most expensive group (US $278 million), largely due to high production costs in the age-group of 20-64 years.

Conclusions

Hand and wrist injuries constitute not only a substantial part of all treated injuries, but also represent a considerable economic burden. In this population-based study, we found both high healthcare and productivity costs, with the latter making the largest contribution. This study shows that these injuries should be a priority for research in trauma care, and further research could help reduce the cost of these injuries, both to the healthcare system and to society.

INTRODUCTION

Injuries to the hand and wrist account for approximately twenty percent of the attendances at the emergency departments (ED).[1,2] Besides the impact of hand and wrist injuries on physical and mental health, they can lead to high healthcare costs and prolonged time off work.[3-11] As a consequence, these injuries may impose a considerable economic burden to community.

Because of rising healthcare costs, economic analyses are considered increasingly important.[12] So far, only a few single-centre studies have estimated the costs of hand and wrist injuries, and population-based studies on this topic are scarce.[13-25] From previous studies we know that productivity costs due to work absenteeism generally are even larger than healthcare costs.[26] Population-based information about these economic production losses could therefore be important to policy makers in the area of injury control, but has not yet been analysed for hand and wrist injuries.

The purpose of this nationwide study was to examine healthcare costs and productivity costs due to hand and wrist injuries, and to compare these costs with those of the other main injury groups. In addition, we examine how these costs are distributed by age-category, gender and different subgroups of hand and wrist injuries. Information obtained from this study can be useful to set priorities in trauma research and trauma care.

PATIENTS AND METHODS

Model description

Healthcare in the Netherlands is financed by a dual system. For all regular (short-term) medical treatment, there is a system of obligatory health insurance covering the whole population, with private health insurance companies. These insurance companies are obliged to provide a standard package of insured treatments as defined by the Dutch government. Long-term treatments, especially those that involve semi-permanent hospitalisation and disability costs, are covered by a state-controlled mandatory insurance for the whole population.[27]

We calculated direct healthcare costs of injury and productivity costs due to work absenteeism. Annual incidence rates of ED visits were extracted from the Dutch Injury Surveillance System for non-hospitalized patients and the National Hospital Discharge Registry for hospitalized patients. In the Dutch Injury Surveillance System, all injuries treated at the ED are recorded, and similar methods in prior studies from other countries are applied.[28,29] Thirteen hospitals participated in this injury surveillance system during the study period, including 3 university hospitals and 10 general hospitals. These geographically-separated hospitals were selected to draw from both rural and urban areas and form a sample of 12% of the total number of injury patients presenting at the EDs in the Netherlands (population of 16.5 million in 2009). The adherence population of the participating hospitals in this study is representative for the Dutch population in age and gender structure and can be extrapolated to national estimates.[30,31] Injury diagnoses and injury mechanisms are registered by using the International Classification of Diseases of the World Health Organization (ICD 10th revision). We considered all patients with injuries to the hand and wrist (S52.5, S52.6, S62.0, S62.1, S62.2-8, S63.0-7, S64.0-9, T11.3, S65-S69, T04.2, T05.0, T05.1, T11.4-9, S60.0-9, and S61.0-9 of the ICD 10th revision, Appendix A). Incidence was restricted to patients who attended an ED, so patients were excluded who were fully treated by primary care practitioners without hospital referral. Injury patients were selected based on the registered primary diagnosis, according to the Eurocost classification of diagnostic groups as developed and recommended by European experts.[30,32] In case of multiple injuries, the primary injury was determined by application of an algorithm giving priority to spinal cord injury, skull/brain injury, lower extremity injury above injuries in other body parts, and to fractures above other types of injury.[3,9,33]

Healthcare costs

To estimate the direct healthcare costs for 2007, we used a previously reported incidence-based cost model, and has been used in 10 European countries (Figure 1).[3,32-36] Per injury group, the number of patients, healthcare consumption and related costs were calculated based on the registered data in the Dutch Injury Surveillance System, on the Hospital Discharge Registry and on a patient survey.

Healthcare consumption was divided into multiple categories in which all relevant types of medical care are used: before, during, and after ED attendance (see resources in Table 1). For each type of healthcare service we used the costs per volume unit that reflects the real resource. All resources in table 1 were retrieved from separate data systems. In case of overlap between systems the costs were attributed to only one data system. For example, if a patient attended the ED and subsequently was admitted, then the costs made at the ED were attributed to the ED data system, while the costs of admission were only attributed to the Hospital Discharge Registry data system. We calculated lifetime healthcare costs of injury by multiplication of incidence, transition probabilities (e.g. chance of hospital admission), healthcare volumes (e.g. length of stay) and unit costs (e.g. costs per day of hospitalization). Incidence, transition probabilities and healthcare volumes were subdivided by patient groups that are homogeneous in terms of health service use.[37]

Healthcare volumes were estimated with national registration data and a patient follow-up survey. A patient follow-up was performed among a sample of 9,907 injury patients who had attended one of the EDs between February 1st 2007 and January 31st 2008. Data were collected on inhospital care, outpatient visits, general practitioner visits, outpatient physical therapy, home care, medication and aids and appliances. In our cost model, hand surgeon visits are included in outpatient visits. However, in the Netherlands, not all patients with injuries to the hand and wrist are treated by hand surgeons. Some of these patients are also treated by other specialties, such as general surgeons or orthopaedic surgeons. The costs of an outpatient department visit are the same for the different specialties and therefore the same unit price was used for all these visits. Hospitalized patients and severe, less common injuries were overrepresented in the sample. Victims from self-inflicted injury and institutionalized persons were excluded. Postal questionnaires were sent 2, 5 and 9 months after the injury event.[38,39]

Figure 1 Structure of the incidence-based cost model used in this study

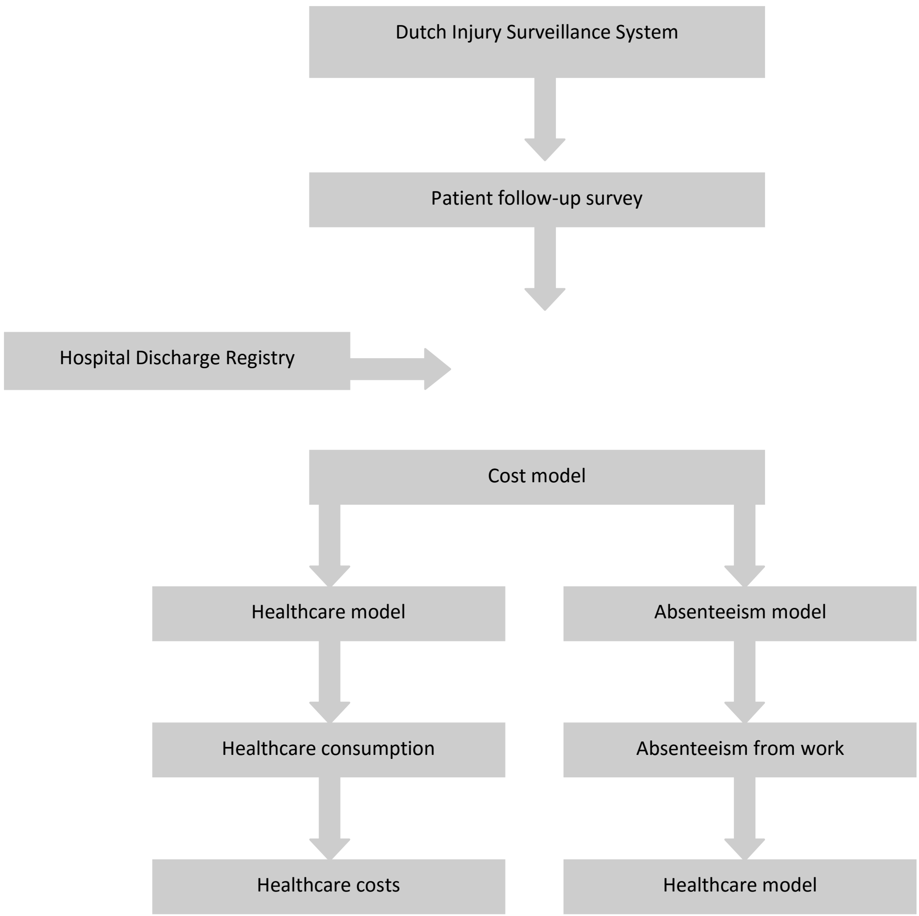


Table 1 Unit costs

Resource	Unit costs (US $) [a]
GP consultation	47
Attendance of Emergency Department [b] (range)	308 (240-836)
Out patient department visit	225
Day case (inpatient procedure)	819
Hospitalization (cost per day)	
University hospital	787
General hospital	581
Intensive care (cost per day)	2208
Medical procedures	Reimbursement fees
Nursing home (cost per day)	301
Home care (cost per hour)	
Domestic care	32
Nursing care	59
Rehabilitation	
Cost per day	492
Cost per hour of treatment	122
Physical therapy (cost per visit)	33
Ambulance journey	
Emergency journey	678
Scheduled journey	260

a: US dollar in 2007
b: Average costs, depending on injury diagnosis and severity. Costs are based on time deployment, medical staff, and materials.

Productivity costs

Productivity costs were defined as the costs associated with production loss and replacement, due to illness, disability and premature death.[40] In the Netherlands, the patient receives financial compensation by the employer during the time out of work, consisting of 70% of the patient's monthly wage. We used the absenteeism model to estimate productivity costs for all patients between 15 and 64 years. In this model the friction-cost method was used, because healthcare needs are most substantial in the first year post-injury for the vast majority of injuries.[10] The essence of the friction cost method is that in case of unemployment absent workers will be replaced after an adaptation period (the friction period) and in this way further productivity costs may subsequently be prevented. [41]

Data were retrieved from an injury surveillance system patient survey with questions relating to work absence, absence duration, and return to work. These questions were only asked to injury patients with paid jobs, to obtain information on absenteeism.[9] The observed duration of absenteeism in working days was converted into the costs of absenteeism according to age, gender and type of injury, using the value-added per employment hour. In national accounts, the net value added equals the total monetary value generated by all units engaged in production activities. We divided the net value added (obtained from Statistics Netherlands) through the total number of hours worked to calculate the productivity of one hour worked. This net value added per employment hour was adjusted for age and gender using the mean wage per category. We estimated the probability of employment within the injured population using labor participation figures derived from the Injuries and Physical Activity in the Netherlands (IPAN) survey. This is a continuously executed telephone survey among a sample of 10,000 Dutch citizens on accidents and sports injuries. These outcomes were adjusted for age using the national age distribution within the employed and unemployed population from Statistics Netherlands.[42]

To calculate probabilities of work absenteeism, independent variables were tested as significant predictors of work status in forward step multivariate regression analyses. We included an injury-by-hospitalization interaction term to test whether the distribution of work status by type of injury was significantly different between patients who were not hospitalized or were hospitalized. Adjustment for stratification could influence the identification of significant independent variables. To avoid this, we used bootstrap analysis (a re-sampling method) by which a specified number of population samples are drawn (iterations). The distribution of the drawn populations across the variables provides information about the significance of each variable. We performed 500 iterations to test the significance levels. The most significant variable was entered into the model and the other variables were subsequently entered. This procedure was repeated until none of the variables was significant. The 95% confidence intervals of the variables in de univariate and final multivariate models were determined by using the 2.5% lowest and highest percentiles of 500 iterations. The probabilities of work absenteeism were multiplied with the average duration of absenteeism, classified by age, gender, type of injury and admission status.[9] Finally, the estimated absenteeism in days was multiplied by the age- and gender-specified productivity cost. All costs are reported in US dollars and we used the year 2007 average exchange rate for conversion from Euros to US dollars (€1.00 = US $1.37).

RESULTS

Injury incidence, healthcare costs and productivity costs

The total number of injury patients treated at the EDs in the Netherlands in 2007 was estimated at 920,000 (57% males, 43% females), resulting in an injury incidence of 56 per 1,000 person-years. The total costs of injuries in the Netherlands were US $4.4 billion, divided into US $2.5 billion direct healthcare costs and US $1.9 billion productivity costs (Table 2).

Hand and wrist injuries accounted for US $740 million in 2007 and ranked first in the order of most expensive injury types, before knee- and lower leg fractures (US $562 million) hip fractures (US $532 million) and skull-brain injury (US $355 million). An amount of US $411 million (56% of the costs due to hand and wrist injuries) was related to productivity costs. The high productivity costs are also reflected in the age distribution, showing that people of working age (20-64 years) were responsible for about 75% of all costs due to hand and wrist injuries (Figure 2a & 2b). This was due to the large contribution of productivity costs in this age group (US $192 million) in males.

Table 2 Healthcare and productivity costs of the most expensive injury types (in US dollar) in 2007

	Number	Cases	Healthcare costs	Healthcare costs per case	Productivity costs	Productivity costs per case	Total costs
	(*1000)	(per 100,000)	($ million)	($)	($ million)	($)	($ million)
Hand and wrist injuries	260	1575	329	1265	411	1580	740
Knee-lower leg fractures	66	400	233	3530	329	4985	562
Hip fractures	15	90	480	32000	52	3465	532
Superficial injuries*	270	1600	301	1115	107	400	408
Skull brain injury	32	200	136	4250	219	6845	355
Other	277	1700	988	3570	801	2890	1789
All injuries	920	5600	2467	2680	1919	2085	4386

** superficial injuries to hand or wrist excluded*

Figure 2a Total healthcare and productivity costs (U.S. dollars in millions) due to hand and wrist injuries in the Netherlands in 2007, according to gender and age category (M = males, F= females)

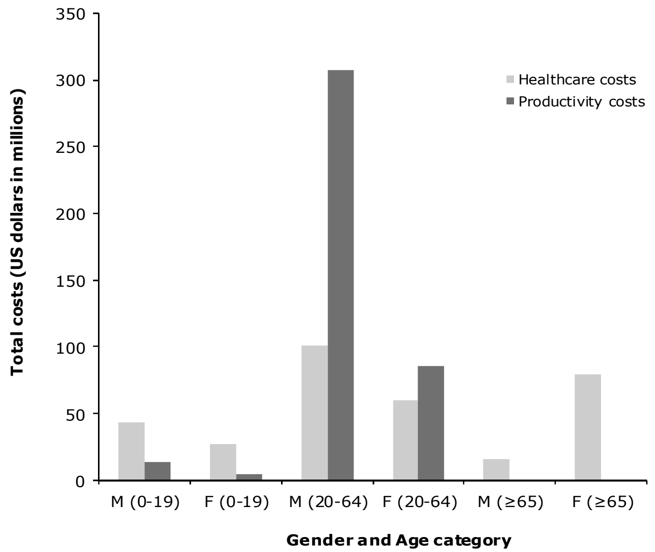
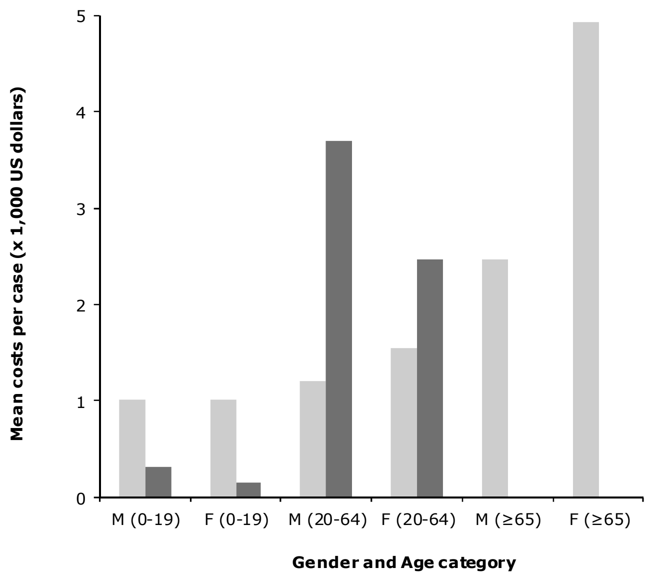


Figure 2b Mean healthcare and productivity costs per case (U.S. dollars in thousands) due to hand and wrist injuries in the Netherlands in 2007, according to gender and age category



Within the overall group of hand and wrist injuries (Table 3), hand and finger fractures were the most expensive group (US $278 million), again largely due to the age group of 20-64 years (US $236 million). Fractures of the hand and finger are responsible for almost half of the total productivity losses, due to a combination of the high number of fractures in the age group 20-64 years (working age group) and high costs per patient because of their longer time off work compared to even more frequently occurring injuries, such as open wounds or superficial injuries.

Wrist fractures cause high healthcare costs per patient, especially at the age over 65, and therefore represent high total healthcare costs. More than half of the patients with hand and wrist injuries have open wounds or superficial injuries, but they account for less than 10% of the observed economic burden. This group has relatively low healthcare costs per case, and low productivity loss. The number of patients with complex soft tissue injuries (e.g. crushing injury or traumatic amputation) was low, but at the individual patient level these injuries cause both high healthcare costs and productivity loss.

Table 3 Healthcare and productivity costs of hand and wrist injuries in the Netherlands in 2007 (in U.S. dollars)

	Number	Cases (per 100,000)	Healthcare costs ($ million)	Healthcare costs per case ($)	Productivity costs ($ million)	Productivity costs per case ($)	Total costs ($ million)
Hand and finger fractures							
0-19 years	19000	480	19	1000	8	400	27
20-64 years	28000	280	44	1600	192	6900	236
≥65 years	4000	170	15	380	-	-	15
Subtotal	51000	310	78	1500	200	3900	278
Wrist fractures							
0-19 years	24000	600	29	1200	4	170	33
20-64 years	13000	130	25	1900	82	6300	107
≥65 years	10000	420	60	6000	-	-	60
Subtotal	47000	290	114	2400	86	1800	200
Open wounds							
0-19 years	12000	310	7	600	1	90	8
20-64 years	47000	470	34	700	31	700	65
≥65 years	3800	160	6	1600	-	-	6
Subtotal	62800	390	47	750	32	500	79
Superficial injuries							
0-19 years	32000	810	18	560	1	30	19
20-64 years	39000	390	31	800	16	400	47
≥65 years	3900	160	8	2000	-	-	8
Subtotal	74900	460	57	750	17	230	74
Complex soft tissue injuries							
0-19 years	1700	43	3	1800	1	600	4
20-64 years	5700	57	14	2500	50	8800	54
≥65 years	480	20	2	4200	-	-	12
Subtotal	7880	48	19	2400	51	6500	70
Dislocation, sprain, strains							
0-19 years	4600	120	4	900	1	200	5
20-64 years	7100	70	9	1300	24	3400	33
≥65 years	810	34	1	1200	-	-	1
Subtotal	12510	76	14	1100	25	2000	39
Injury of the upper extremity nerves	90 *	0,53 *	-	-	-	-	*
Total	260000	1575	329	1265	411	1580	740

**number of patients too low for reliable estimation of costs*

DISCUSSION

Hand and wrist injuries are the most expensive injury category, outranking hip fractures, knee- and lower leg fractures and skull-brain injuries. We estimated the healthcare costs of hand and wrist injuries in the Netherlands to be US $329 million, and productivity costs of US $411 million. The age group 20-64 years was responsible for about 75% of all costs due to hand and wrist injuries, mainly due to the high productivity costs in this age group. Within the overall group of hand and wrist injuries, fractures of hand and finger were the most expensive group, largely due to the age group of 20-64 years. Wrist fractures cause high mean healthcare costs per patient, especially at the age over 65, and therefore also high total healthcare costs.

A major strength of the present study is that it is based on population-based nationwide inpatient and outpatient data on the incidence and costs of hand and wrist injuries. Registries with national coverage were used to analyse the healthcare resources that are most important for injuries, such as hospital inpatient care, medical procedures, rehabilitation treatment, and nursing home care and long-term care at home. International validation studies, including data systems of 10 European countries, have shown that the Dutch Injury Surveillance System has a high level of completeness and validity.[30,31] Furthermore, this study presents a comprehensive incidence-based cost model in which both healthcare and productivity costs were included for all injuries.[10,32] Because a uniform coding method has been used to estimate the costs, it was possible to compare the healthcare use and related healthcare costs of all types of injuries with a uniform methodology. The incidence-based cost model was developed in The Netherlands, but has been used in 10 European countries. This has shown similar distributions by age, gender and injury type in other countries as in The Netherlands. Furthermore, previous cost-of-illness studies from the Dutch National Institute of Public Health and the Environment (RIVM) produced similar results for injury costs as our model.[31,35,36]

In calculating productivity costs, the absenteeism model estimates the costs for the first year after injury. In this study we used the friction-cost method because in the majority of injuries healthcare needs are most substantial in the first year post-injury.[10] In health economics several methods have been proposed to estimate the costs due to economic production losses. Many previous cost-of-illness studies and economic analyses have used the human-capital method. In the human-capital method productivity loss is considered from the patient's perspective, and calculated as the product of the total hours of lost productivity until the age of retirement in a population, and the hourly wage. While many previous studies used the human-capital method, this approach has often been criticized because of overestimating the magnitude of productivity costs. The friction cost method more accurately measures productivity costs, because it takes into account that in case of unemployment absent workers will be replaced after an adaptation period. [40,41,44]

An inherent limitation of a population-based survey of this scale is the lack of available clinical details of the injury, for example on the anatomic location of a fracture, on the fracture type, or whether the fracture was open or closed. This was due to the use of non-specific fracture codes, such as wrist fracture, including distal radius fractures and fractures of the carpal bones. Therefore, the precise distribution of distal radius fractures and carpal fractures is not known. We used a broad classification system, which aggregated several severe injuries (traumatic amputations, crush injuries, and injuries to blood vessels, muscles and tendons) in one single category: complex soft tissue injuries (Appendix A). Despite the heterogeneity of this injury category, this limitation will not have influenced the cost estimates importantly because of the low frequencies on population level. Another limitation of this study is that we only included patients who attended the ED. In the Netherlands, there are specialized hand surgery centres that treat patients outside of a hospital. However, these centres generally perform elective surgery and almost all patients with acute injuries to the hand or wrist are treated at the ED or by a general practitioner. In 2007, approximately 920,000 injury patients visited an ED, and the same number of patients were treated by a general practitioner or other primary healthcare providers. Most patients treated outside the hospital have minor injuries, like cuts, abrasions, dislocations, sprains and strains. For this reason, and assuming that the cost per patient is not different from the costs per patient with minor injuries treated at the ED, we have estimated that they will add only 2-5% to our cost estimate.

A previous study from the Netherlands showed that the costs due to injuries are comparable with those of cancer and stroke.[3,12] However, this is the first population-based study that shows that the total costs of hand and wrist injuries are a real economic burden to society, and compares both healthcare costs and productivity costs with expenditures on other main injuries, like hip fractures and skull-brain injuries. This comprehensive approach hampers a straightforward comparison with other studies using other analysis methods and populations. A previous population-based study from the Netherlands estimated healthcare costs due to all injuries to be US $1.58 billion in 1999, resulting in US $90 per capita for males, and US $108 for females.[3] Fractures were expected to have the highest costs of all injuries, due to possible admissions, longer rehabilitation, plaster treatment, X-rays and surgery. This study found hip fractures to be the most expensive injury group in proportion of healthcare costs, representing 20.4% However, the study did not estimate productivity costs. In the same study, the proportion of healthcare costs due to fractures of the wrist, hand and fingers together represented 6.3% of the total costs. Total healthcare costs were lower compared to ours, what may largely be explained by the fact that data used in that study were derived from 1999.

Hand and wrist injuries contributed to a notable amount of injury related healthcare expenses, especially due to productivity costs, which is seen in other Western countries as well. Rosberg et al. reported costs due to lost production after hand injuries to be 67% of the total costs, while Trybus et al. estimated the proportion production costs up to 96%.[14,15] Other Swedish studies analysed treatment and rehabilitation costs of a nerve injury for an employed person and found productivity costs to be 87% of the total costs, and 55-65% for tendon injuries.[16,17] The proportion productivity costs for hand and wrist injuries in our study (56%) is comparable or even lower compared with those found in most previous clinical studies. Differences are probably due to variation in methods used to obtain data or case mix, different costs elements, time periods and different health care and social security systems. For example, Day et al. reported that patients with hand and wrist disorders who receive compensation contribute to increased healthcare costs, and spend longer periods of time out of work than do patients who are not receiving compensation.[43]

The results of this study provide an important message for both clinical research and public health policies since it provides insight into the areas where most costs are made. Clinical research on surgical and rehabilitation interventions of hand and wrist injuries that aim to lower the time off work may have a large economic potential, for example minimal invasive surgery techniques, or early active mobilisation therapy. It has been shown that a patient-oriented rehabilitation-programme after hand surgery reduces time of work[45] and that early dynamic motion after tendon transfers can shorten rehabilitation time.[46] In the field of public health, epidemiological research may elucidate the main causes of, for example, hand- and finger fractures, to develop prevention strategies targeted at the most costly injuries.

In conclusion, hand and wrist injuries constitute not only a substantial part of all injuries at the ED, but also represent a considerable economic burden to society. In this population-based study, we found that these injuries have both high healthcare and productivity costs, with the latter making the largest contribution. This study shows that these injuries should be a priority for research in trauma care, and further research could help reduce the cost of these injuries, both to the healthcare system and to society.

APPENDIX

Diagnostic groups used in this study and corresponding ICD-10 codes

Blocks of ICD chapter XIX	**Diagnostic group**
S52.5: Fracture of the distal radius S52.6: Fracture of lower end of both ulna and radius S62: Fracture at wrist and hand level S62.0: scaphoid fracture S62.1: fracture other carpal bones	Wrist fracture
S62: Fracture at wrist and hand level S62.2-S62.8	Fracture of hand and fingers
S63: Dislocation, sprain and strain of joints and ligaments at wrist and hand level S63.0-S63.7	Dislocation/sprain/strain wrist/hand/fingers
S64: Injury of nerves at wrist and hand level S64.0-S64.9 T11.3: Injury of unspecified nerve of upper limb, level unspecified	Injury of upper extremity nerves
S65: Injury of blood vessels at wrist and hand level S66: Injury of muscle and tendon at wrist and hand level S67: Crushing injury of wrist and hand S68: Traumatic amputation of wrist and hand S69: Other and unspecified injuries of wrist and hand T04.2: Crushing injuries involving multiple regions of upper limb(s) T05.0: Traumatic amputation of both hands T05.1: Traumatic amputation of one hand and other arm [any level, except hand] T11.4: Injury of unspecified blood vessel of upper limb, level unspecified T11.5: Injury of unspecified muscle and tendon of upper limb, level unspecified T11.6: Traumatic amputation of upper limb, level unspecified T11.7: Traumatic amputation of arm, level specified T11.8: Other specified injuries of upper limb, level unspecified T11.9: Unspecified injury of upper limb, level unspecified	Complex soft tissue injury of the upper extremity
S60(.0-.9): Superficial injury of wrist and hand	Superficial injury of wrist and hand
S61(.0-.9): Open wound of wrist and hand	Open wounds

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Chapter 6

Hand and Wrist Injuries by External Cause:

A population-based study in working-age adults, 2008-2012

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ABSTRACT

Purpose

Hand and wrist injuries are very common at the Emergency Departments (ED), and among the most costly injury types in the working population. The purpose of this study was to explore the causes and costs of non-trivial hand and wrist injuries (i.e. hand fractures, wrist fractures and complex soft-tissue injuries) in working-age adults in order to identify target areas for prevention.

Methods

Data were extracted from the Dutch Injury Surveillance System, from the National Hospital Discharge Registry and from a patient follow-up survey in working-age adults (aged 20-64 years) in the period 2008-2012. Total costs were calculated by external cause, subdivided in their main categories (home, sports, work, traffic and violence) and their most important subclasses.

Results

Total costs of these injuries in the Netherlands were US $410 million per year, of which 75% (US $307 million) productivity costs. Males represented 66% (US $271 million) of the total costs. Within the male group, the group 35-49 years had the highest contribution to total costs (US $112 million), as well as the highest costs per case (US $10675). The top five causes in terms of total costs were: accidents at home (falls 23%, contact with an object 17%), traffic (cycling 9%) and work (industrial work 4%, and construction work 4%).

Conclusion

Hand and wrist injuries are a major cause of healthcare and productivity costs in working-age adults. To reduce the costs to society, prevention initiatives should be targeted at major contributing causes, that are mainly related to activities at home (falls, contact with an object) and accidents at the road (cycling).

INTRODUCTION

Hand and wrist injuries are very common at the Emergency Department (ED). These injuries are frequent work-related and are also one of the most costly injury types.[1-4] Hand and wrist injuries can occur during a wide variety of activities at home, during recreation, in traffic and at work.[5-7] Therefore, to define target areas for prevention, and to reduce costs, it is important to study the underlying causes.

Research has already provided some insight into the costs of upper extremity injuries and injuries to the hand and arm and hand [8-11], but an analysis of the most important causes of the costs of hand and wrist injuries is lacking. Our group previously demonstrated that the high costs of hand and wrist injuries are mainly related to lost productivity due to absenteeism resulting from non-trivial hand and wrist injuries (i.e. hand fractures, wrist fractures and complex soft tissue injuries) in the working population.[3]

The current study extends this analysis and aims to determine the most important causes of the costs non-trivial hand and wrist injuries in working-age adults in the Netherlands.

PATIENTS AND METHODS

Data sources

The absolute number of annual ED visits in the period 2008-2012 were retrieved from the Dutch Injury Surveillance System (for non-hospitalized patients) and the National Hospital Discharge Registry (for hospitalized patients). In the Dutch Injury Surveillance System, all injuries treated at the ED of the fifteen participating hospitals are recorded. These hospitals form a representative sample of 12% of the patients attending EDs in the Netherlands (16.8 million inhabitants in 2012), and estimations can be made to national level.[12,13] Injury diagnoses and injury mechanisms are registered by using the International Classification of Diseases of the World Health Organization (ICD 10th revision). We included patients (aged 20-64 years) with non-trivial hand and wrist injuries (i.e. hand fractures, wrist fractures and complex soft-tissue injuries; ICD 10th revision, see Chapter 5). Patients were selected based on the registered primary diagnosis, according to the Eurocost classification of diagnostic groups, as developed and recommended by European experts.[14,15] Causes of injury were routinely recorded according to the International Classification of External Causes of Injuries, divided over five categories (home, sport, work, traffic and violence), as well as their main subcategories.[16]

Healthcare costs

To estimate healthcare costs for 2012, our previously described incidence-based cost-model was used.[3,17] For each injury group, healthcare consumption and related costs were calculated based on data in the Dutch Injury Surveillance System, the National Hospital Discharge Registry, and a patient follow-up survey conducted in 2012. In this model, the age and injury-specific costs are based on the estimated healthcare consumption of the individual patient. Healthcare costs were calculated by multiplication of the incidence, healthcare volumes (e.g. length of stay) and unit costs (e.g. costs per day in hospital; see Chapter 5).

Productivity costs

We used our previously described absenteeism model to estimate productivity costs.[3,17] We used the friction-cost method in this study, because in the majority of patients the largest proportion of healthcare needs are made during the first year after the injury. The friction-cost method is based on the fact that in case of unemployment the absent worker will be replaced after an adaptation period (the friction period). Within the patient follow-up survey, questions relating to work absence, days lost from work, and return to work were included. The observed duration of absenteeism in working days was converted into the costs of absenteeism according to age, gender and type of injury, using the value-added per employment hour. In national accounts, the net value added equals the total monetary value generated by all units engaged in production activities. We divided the net value added (obtained from Statistics Netherlands) through the total number of hours worked to calculate the productivity of one hour worked. This net value added per employment hour was adjusted for age and gender using the mean wage per category.[3] Finally, the estimated absenteeism in days was multiplied by the age- and gender-specified productivity cost. All costs are reported in US dollars and we used the year 2012 average exchange rate for conversion from Euros to US dollars (€1.00 = US $1.29).

RESULTS

During the study-period, approximately 56,000 patients (aged 20-64 years, 57% males) with non-trivial hand and wrist injuries were annually treated at the ED, resulting in an age-standardized incidence rate of 635.2 (per 100,000 persons; 95% CI, 578.0 to 692.4) for males, and 479.1 (95% CI, 436.0 to 522.2) for females. In both males (42.8%) and females (62.1%), hand and wrist injuries most frequently occured at home. In males, work-related injuries rank second (21.9%), whereas the contribution to hand and wrist injuries in working-age females is low (4.6%; Table 1).

The total costs were estimated at US $410 million per year, with 75% (US $307 million) productivity costs. Males represented 66% (US $271 million) of the total costs. Within the male group, the group 35-49 years had the highest contribution to total costs (US $112 million), as well as the highest costs per case (US $10675; Figure 1). Males in the age-groups 20-34 and 35-49 years had two to four times higher total costs (for both healthcare costs and productivity costs) than females in these age-categories. In both males and females healthcare costs and healthcare costs per case increased with increasing age.

Figure 1 Gender and age-specific healthcare costs and productivity costs (million US dollars) and mean costs per case (US dollars) due to non-trivial hand and wrist injuries in the Netherlands in 2012

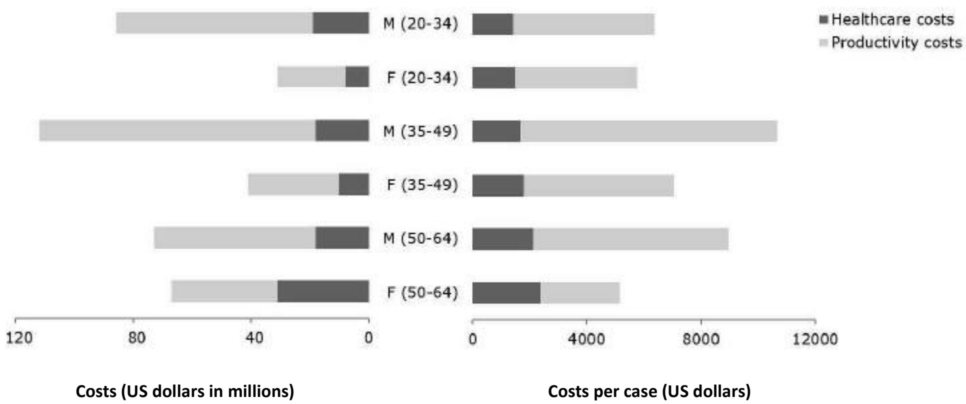


Table 1 Average annual number of patients (aged 20-64 years) with non-trivial hand and wrist injuries in the Netherlands (2008-2012), according to gender and external cause.

	Males (%) (n = 32211)	Females (%) (n=24066)
Home		
Fall	17.2	45.0
Contact with object	21.6	12.7
Contact with person	1.5	1.7
Overuse	0.8	1.2
Other	1.7	1.5
Subtotal	42.8	62.1
Sport		
Hockey	1.2	1.2
Soccer (outdoor)	6.2	0.7
Soccer (indoor)	0.8	0.1
Skiing	0.5	0.5
Fight sports	1.0	0.2
Other	9.4	16.2
Subtotal	19.1	18.9
Work		
Agriculture	1.6	0.3
Industry	3.8	0.3
Construction work	4.2	*
Trading and Services	5.3	2.7
Other	7.0	1.3
Subtotal	21.9	4.6
Traffic		
Pedestrian	0.2	0.3
Cyclist	7.4	9.8
Moped	1.4	1.0
Motorcycle, scooter	2.0	0.4
Car	0.8	1.1
Other	0.3	0.3
Subtotal	12.1	12.9
Violence	4.1	1.5
Total	100	100

**numbers too low for reliable estimation*

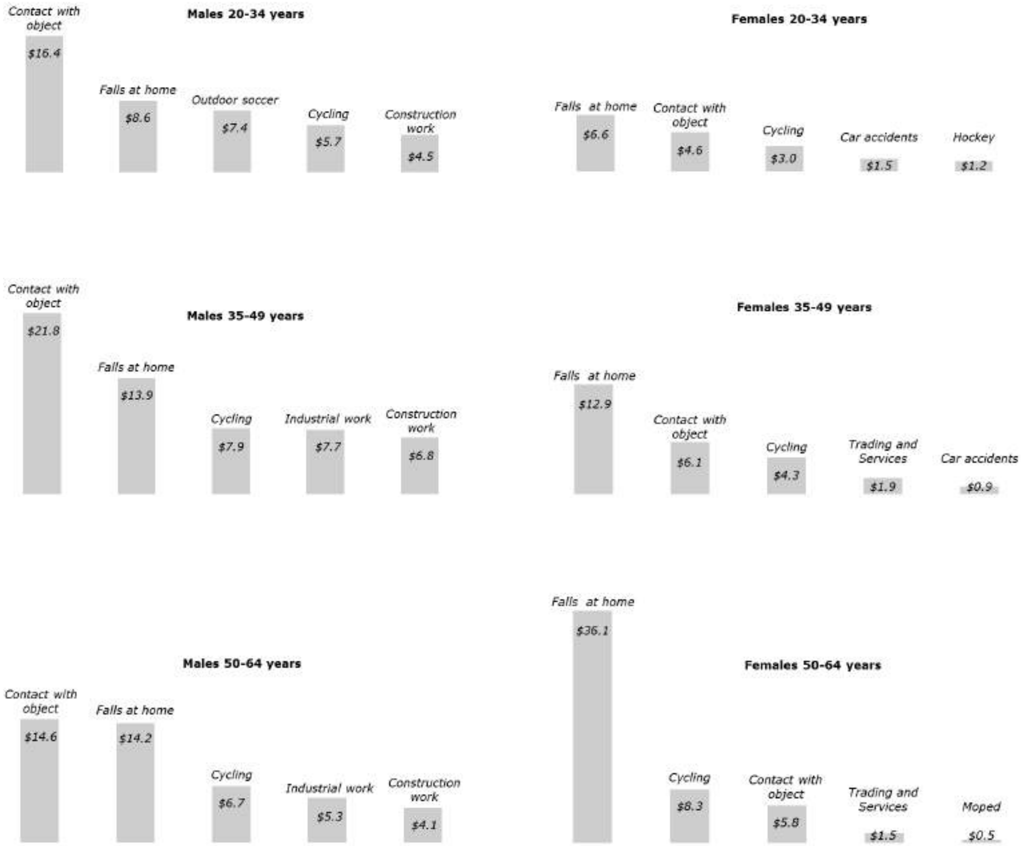
Home-related injuries accounted for US $177 million (mainly due to the high number of injuries), followed by work-related injuries in males (US $83 million) and sports (US $67 million; see Table 2). Males showed the highest costs per case in each cause category, with the highest costs per case in work-related injuries (US $11797), followed by traffic-related injuries (US $10122) and violence (US $7907).

The overall top five of causes of these injuries represent almost 60% of the total costs. In males, the main contributions in each age-category to total costs were accidents at home (falls and contact with an object), followed by sports (outdoor soccer, in the age-group 20-34 years) and traffic (cycling, in the age-groups 35-49 years and 50-64 years); Figure 2. In females, accidents at home represented the main contribution to the total costs (falls, in the age group 50-64 years, followed by contact with an object), followed by traffic (cycling).

Table 2 Gender and cause-specific total costs (million US dollars) due to non-trivial hand and wrist injuries in the Netherlands in 2012

	Males	Females	**Total**
Home	99	78	177
Sport	40	27	67
Work	83	9	92
Traffic	39	22	61
Violence	10	3	13
Total	271	139	410

Figure 2 Top five causes of total costs (million US dollars) due to hand and wrist injuries in the Netherlands (2008-2012), according to gender and age-category



DISCUSSION

This study confirmed that hand and wrist injuries are a major source of healthcare costs and productivity costs in working-age adults. We estimated the total costs due to these injuries in the Netherlands to be US $410 million per year, with 75% (US $307 million) productivity costs, and males representing 66% (US $271 million) of the total costs. The top five causes in terms of total costs are: falls at home (23%), contact with object (17%), cycling (9%), industrial work (4%) and construction work (4%).

This is, to our best knowledge, the first population-based study which analysed causes and total costs (including healthcare costs and productivity costs) of non-trivial hand and wrist injuries in the working-age population. Previous studies analysed the causes and healthcare costs of all injuries, or subgroups such as upper extremity injuries.[11,18] However, hand injuries, productivity costs and their underlying causes were not analysed separately. Rosberg et al. analysed costs of serious hand and arm injuries, and showed that work-related injuries represented the highest costs in a single-center study, and reported a 69% higher risk of hospitalization in work-related injuries compared to leisure-time related injuries.[19] In this study, home-related injuries represented the majority of costs, followed by work-related injuries and sports. We found two to four times higher healthcare costs and productivity costs in males (age groups 20-34 and 35-49 years) than females in these age-categories. The higher costs might partly be explained by the fact that injuries in males were more often related to work, traffic and violence, which have higher costs-per-case and prolonged time-off-work. Another factor contributing to higher population costs in males, is the higher male labour participation rate.[20]

The main strength of the present study is that we performed a comprehensive, population-based analysis on hand and wrist injuries. We used a nationwide database, including both hospitalized and non-hospitalized patients. The Dutch Injury Surveillance System has a high level of completeness and validity, as previously shown.[12,14] In addition, we were also able to analyse both healthcare costs and productivity costs, as well as the underlying causes of these injuries.

A limitation of the present study was that patients were included based on the recorded primary diagnosis. In the case of multiple injuries, the primary injury was determined by application of an previously described algorithm, giving priority lower extremity injury above injuries in other body parts, and to fractures above other types of injury.[3,17,18] Another limitation is that we included the non-trivial hand and wrist injuries only (i.e. hand fractures, wrist fractures and complex soft-tissue injuries) because these injuries are treated at the ED. These injuries represent 31% of all hand and wrist injuries, however, they represent up to 75% of the total costs.[3] We excluded open wounds, superficial soft-tissue injuries and sprains and strains, because a substantial proportion of these patients could be treated by the general practitioner (and are not referred to the ED), and therefore the underlying cause will not be registered in the database.

The results of this study are important for public health initiatives, because the main contributions to total costs due to hand and wrist injuries are shown. Besides the clinical indicators of care, these economic analyses can provide additional information. The estimation of costs may help decision makers to make better choices, in terms of prevention and research priorities, for example prevention of falls at home and cycling-related injuries.[21-24] Many previous studies have shown fall prevention strategies in elderly to be effective[23], however little is known about fall prevention in working-age adults. For cyclists, a recent study showed an increase in traumatic injuries and hospital admissions, especially in adults above 45 years.[21] Besides the use of helmets to prevent head injuries, further research should also focus on trends in bicycle-related upper extremity injuries, as well as potential risk factors, such as behaviour and infrastructure.[25-27] A recent study showed an increasing trend in electric bike-related injuries, and therefore trends in these injuries should be evaluated regularly.[28,29] For males, future prevention strategies should focus on industrial and construction workers, and home-related injuries due to contact with object (such as do-it-yourself jobs at home). Despite diverging trends in work-related injuries, prevention strategies should still be targeted at these injuries to decrease their large economic burden.[4,30,31] For injuries due to contact with object, such as due to do-it-yourself jobs at home, prevention initiatives should focus on education and awareness of safety. The rate of injuries might be reduced after training in the use of (garden) tools, and how to use them properly.[32-34]

In conclusion, this study showed that hand and wrist injuries are a major source of productivity costs in working-age adults. To reduce the costs to society, prevention initiatives should focus on major contributing causes, that are mainly related to activities at home and at the road.

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Chapter 7

Health-Related Quality of Life after Upper Extremity Injuries and Predictors for Suboptimal Outcome

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ABSTRACT

Purpose

To examine the impact of upper extremity injuries (UEI) on health-related quality of life (HRQoL) in adult patients compared with victims of other types of injuries and with the general population, in order to establish recovery patterns of different types of UEI and determine predictors for suboptimal outcome in the long term.

Methods

Data were obtained from the Dutch Injury Surveillance System, from the National Hospital Discharge Registry, and from a patient follow-up survey. Included were 608 patients (aged 18 years and older) with an UEI. Main outcome measure was HRQoL measured at 2.5, 5, 9 and 24 months after UEI according to the EuroQol-5D (EQ-5D). Predictors for suboptimal outcome were examined by multivariate linear regression analyses.

Results

For non-hospitalized UEI patients, a substantial loss in HRQoL was observed after 2.5 months which improved to the level of the general population norms by 24 months. For hospitalized UEI patients, HRQoL improved from 2.5 months to 24 months but remained far below population norms. At all time points, the proportion of UEI patients with limitations on the health domains self-care, usual activities and complaints of pain and/or discomfort was higher than in the group of all injuries. Female gender, higher age, low educational level, comorbidity, shoulder or upper arm injury, multiple injuries and hospitalization are independent predictors for long-term loss in HRQoL.

Conclusions

The presence of UEI substantially reduces HRQoL on the short and long term, mainly due to limitations on the health domains self-care, usual activities and complaints of pain and/or discomfort.

INTRODUCTION

Upper extremity injuries (UEI) are frequent in the adult population and lead to substantial use of health services and large production losses.[1-3] As a consequence, UEI represent an economic burden on society. UEI in general, and hand and wrist injuries in particular, are one of the most costly injury types, before lower extremity injuries and skull and brain injuries.[4]

However, the societal impact of injuries extends beyond the economic costs and includes other sequelae, such as functional limitations, pain, psychological distress and decreased social interaction.[5-7] This spectrum of negative consequences is included in generic health-related quality of life (HRQoL) measures, such as patient-reported outcomes reflecting the impact of ill health on several dimensions of human life. Generic HRQoL measures enable straightforward comparisons of injury consequences with general population values and the impact of other diseases, and also allow outcome comparisons between several types of injury affecting different body regions, such as the upper or lower extremity or the head.[8-10]

HRQoL measures are increasingly applied in injured populations and have improved our insight into recovery patterns and non-fatal health outcomes within this field.[11] For example, it has been shown that even injuries of low severity (i.e. without threat to life) may lead to sustained suffering and that far more healthy life-years are lost by non-fatal injuries than by mortality.[12,13] These insights were obtained with the Euro-Qol-5D questionnaire (EQ-5D), a generic HRQoL measure recommended for broad application in the injury field by several international consensus groups.[8,9] This measure is well-fitted for application in comprehensive patient populations covering a broad range of injuries[14] and has also been validated and applied in specific groups of injury patients, such as burns[15,16], lower extremity injuries[17] and specific upper extremity fracture groups.[18-27]

To date, comprehensive population-based studies using this generic outcome measure to examine HRQoL after UEI are lacking. Therefore, the aim of the present study is: 1) to examine the impact of UEI on HRQoL in adult patients at 2.5, 5, 9 and 24 months after injury compared with victims of other types of injuries and with the general population, 2) to compare recovery patterns of different types of UEI, and 3) to determine predictors for suboptimal outcome on the long term.

METHODS

Study population

A prospective follow-up study was performed among patients with UEI aged 18 years and older. Data were retrieved from the Dutch Injury Surveillance System and from the National Hospital Discharge Registry. [28-30] In the Netherlands, all injuries treated at the Emergency Department (ED) are recorded in the injury surveillance system. During the study period, 17 hospitals (14 general hospitals and 3 university hospitals) participated in this injury surveillance system. These hospitals together form a sample of 12% of the patients attending EDs in the Netherlands (16.5 million inhabitants in 2009). The patients visiting these selected hospitals in the injury surveillance system are representative for the Dutch population in age and gender structure, and estimations to the national level can be made.[28,31] In the National Hospital Discharge Registry, individual information on inpatient care is collected on a nationwide basis with almost 100% coverage.

We included all patients with UEI (S42 (.0-.4), S42 (.7-.9), S43 (.0-.7), S45 (.0-.9) to S49 (.0-.9), S52 (.0-.9), S53 (.0-.4), S55 (.0-.9) to S59 (.0-.9), S62 (.0-.8), S63 (.0-.7), S65 (.0-.9) to S69 (.0-.9), T04.2, T05 (.0-.2), T10X, and T11 (.2-.9) according to the International Classification of Diseases of the World Health Organization (ICD 10th revision). Injury patients were included based on the recorded primary diagnosis, as used in the Eurocost classification of diagnostic groups.[28,29] In the case of multiple injuries, the most severe injury was recorded in the injury surveillance system, according to a hierarchical rule. This hierarchical rule gives priority to spinal cord and brain injury, lower extremity injury above upper extremity injury, and to fractures above other injuries. [1,4,29,32]

Chapter 7

Health-Related Quality of Life

A stratified random sample of adult patients (aged 18 years and older) with UEI recorded in the injury surveillance system (n=1,341) received a postal survey on their HRQoL at 2.5, 5, 9 and 24 months after UEI.[32] To increase the number of completed surveys, non-respondents received a reminder. The EQ-5D was used to assess HRQoL on five health dimensions (mobility, self-care, usual activities, pain or discomfort, and anxiety or depression) and a previously developed scoring algorithm was used to express these five health dimensions into a summary score.[33] This summary score, the EQ-5D utility score, ranges from -0.59 (worst possible health state) to 1 (best health state). The EQ-5D utility score of patients at 2.5, 5, 9 and 24 months after UEI was compared with reference values of the general population (aged 18 years and older).[34] Potential determinants of reduced HRQoL were derived from literature.[32] These determinants were classified into sociodemographic (age, gender and educational level), injury (type of injury and multiple injuries), healthcare-related (hospitalized versus non-hospitalized) and comorbidity (defined as the previous presence of disease at the time of injury) determinants. The study was approved by the local Institutional Review Board.

Statistical Analysis

A non-response analysis was performed using multivariate logistic regression. Age, gender, educational level, injury type, hospitalization status and health status (EQ-5D summary score) were tested as possible determinants of non-response. Because response rates varied between the 2.5, 5, 9 and 24-month patient surveys, separate non-response analyses were performed for each survey. We used the significant variables ($p < 0.05$) to adjust for response bias by weighing the respondents with the inverse probability of response. The weighted data are representative for a population of injury patients attending an ED in the Netherlands. About 10% of the patients did not respond to one or more health dimensions of the EQ-5D. Because the summary score can only be obtained in case of complete information on all five health dimensions, the hot deck imputation technique was applied to estimate the missing values. In this method, a missing value is replaced by the value reported by a person with similar scores in the health domain.[32] Sociodemographic and injury-related determinants were identified as predictors of functional outcome in univariate and step-forward multivariate regression analyses. In a multivariate regression analysis we tested gender, age, education, comorbidity, shoulder or upper arm injuries, multiple injuries and hospitalization as potential predictors for long-term loss in HRQoL.

RESULTS

From the patients with UEI that were invited to fill in the surveys, we obtained a completed 2.5-month survey from 608 patients; 440 patients completed the 5-month survey; 425 completed the 9-month survey and 281 completed the 24-month survey. There were minor differences between the respondents and non-respondents; females, elderly and hospitalized patients showed a higher response rate to the first survey. The majority (62%) of UEI was due to home and leisure accidents, and fracture was the most common injury type (78%) (Table 1).

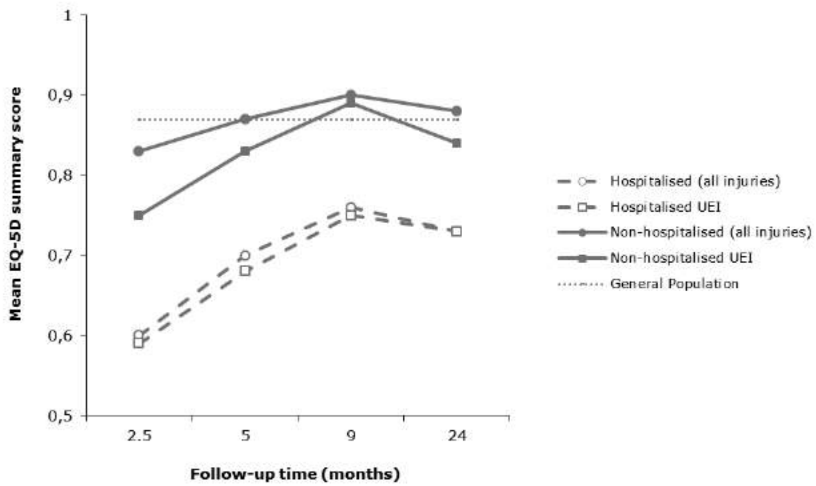
Table 1 Population of upper extremity injuries

	Selected for follow-up (n=1341)		Respondents (weighted*)
	n	%	%
Gender			
Male	688	51.3	32.0
Female	653	48.7	68.0
Age in years			
18-29	278	20.7	15.3
30-49	425	31.7	23.4
50-64	276	20.6	26.5
65-79	230	17.2	25.2
≥ 80	132	9.9	9.6
External cause			
Home and leisure	745	55.6	62.1
Traffic	252	18.8	14.8
Sport	176	13.1	19.5
Occupational	127	9.5	0.4
Violence	13	1.0	3.1
Not known	27	2.0	0.3
Type of injury			
Fracture of clavicle/scapula	200	14.9	11.8
Fracture of upper arm	163	12.2	6.4
Fracture of elbow/forearm	149	11.1	11.7
Fracture wrist	163	12.2	29.7
Fracture hand/fingers	140	10.4	18.1
Dislocation, sprain or strain shoulder/elbow	190	14.2	9.7
Dislocation, sprain or strain wrist/hand/fingers	113	8.4	7.4
Nerve injury upper extremity	24	1.8	0.1
Complex soft tissue injury upper extremity	198	14.8	4.9
Number of injuries			
1	1084	80.9	92.6
2	183	13.7	5.0
≥ 3	73	5.4	2.4
Hospitalization			
Hospitalized	538	40.1	7.0
Non-hospitalized	803	59.9	93.0

Health-Related Quality of Life

For non-hospitalized UEI patients, a substantial loss in HRQoL (0.75) was observed after 2.5 months (Figure 1), which was larger than for non-hospitalized injury patients in general (0.83). HRQoL in non-hospitalized UEI patients improved to the level of general population norms after 24 months (0.84). For hospitalized UEI patients, health impact was more severely reduced. Recovery patterns in this group were similar to those of all hospitalized injury patients. In the hospitalized UEI patients HRQoL improved from 2.5 months (0.59) to 24 months (0.73), but remained far below general population norms (0.87).

Figure 1 Mean EQ-5D summary scores of all injuries compared with UEI in hospitalized and non-hospitalized patients aged 18 years and older



Data are corrected for non-response and stratification, and are representative of an adult population of injured patients who visited an ED in the Netherlands.

Patients with proximal upper extremity injuries, such as upper arm fractures, had lower HRQoL after injury and this HRQoL recovered more slowly than in distal injuries (Table 2). For example, patients with fractures of the hand or finger showed improvement in HRQoL from 0.80 at 2.5 months to 0.90 at 24 months, which is comparable with the general population's health. In patients with upper arm fractures, on the contrary, HRQoL showed a suboptimal improvement from 2.5 months (0.57) to 24 months (0.69).

Table 2 Mean EQ-5D summary score of patients with upper extremity injuries at 2.5, 5, 9 and 24 months post injury.

	EQ-5D summary score							
	2.5 months		5 months		9 months		24 months	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fracture of upper arm	0.57	[0.32]	0.65	[0.29]	0.76	[0.23]	0.69	[0.14]
Fracture of elbow/forearm	0.68	[0.28]	0.78	[0.24]	0.81	[0.26]	0.80	[0.18]
Fracture of clavicle/scapula	0.70	[0.29]	0.83	[0.23]	0.85	[0.17]	0.80	[0.14]
Fracture wrist	0.74	[0.24]	0.81	[0.26]	0.93	[0.12]	0.85	[0.13]
Fracture hand/fingers	0.80	[0.21]	0.89	[0.11]	0.90	[0.12]	0.90	[0.11]
Dislocation, sprain or strain shoulder/elbow	0.72	[0.27]	0.83	[0.19]	0.84	[0.18]	0.83	[0.17]
Dislocation, sprain or strain wrist/hand/fingers	0.82	[0.22]	0.89	[0.15]	0.93	[0.11]	0.86	[0.13]
Nerve injury upper extremity	0.68	[0.10]	0.86	[0.10]	0.86	[0.10]	0.74	[0.03]
Complex soft tissue injuries	0.83	[0.19]	0.86	[0.14]	0.87	[0.22]	0.85	[0.15]

[SD] standard deviation

Multivariate regression analyses have been performed to determine predictors for long-term loss in HRQoL (R^2 = 0.41). Female gender showed, after correction for other confounders, a lower score than males (-0.014). Patients with higher age had lower scores than patients at younger ages (-0.001 per increasing year of age), and patients with low educational level showed lower scores compared to patients with higher education (-0.036). Other independent predictors for suboptimal outcome in the long-term were comorbidity, shoulder or upper arm injury, multiple injuries and hospitalization (Table 3).

Table 3 Predictors for HRQoL of patients with UEI by multivariate regression at 24-month follow-up (aged 18 years and older)

	Beta	*t*	*p*
Gender			
Male	0		
Female	-0.014	-4.95	<0.001
Age			
18 years	0		
Increasing age*	-0.001	-17.95	<0.001
Education			
Higher	0		
Lower	-0.036	-12.11	<0.001
Comorbidity			
Yes	0		
No	0.042	14.63	<0.001
Location			
Shoulder/upper arm injury	0		
Elbow/lower arm injury	0.055	18.94	<0.001
Multiple injuries			
Yes	0		
No	0.020	3.61	<0.005
Hospitalization			
Yes	0		
No	0.110	17.99	<0.001

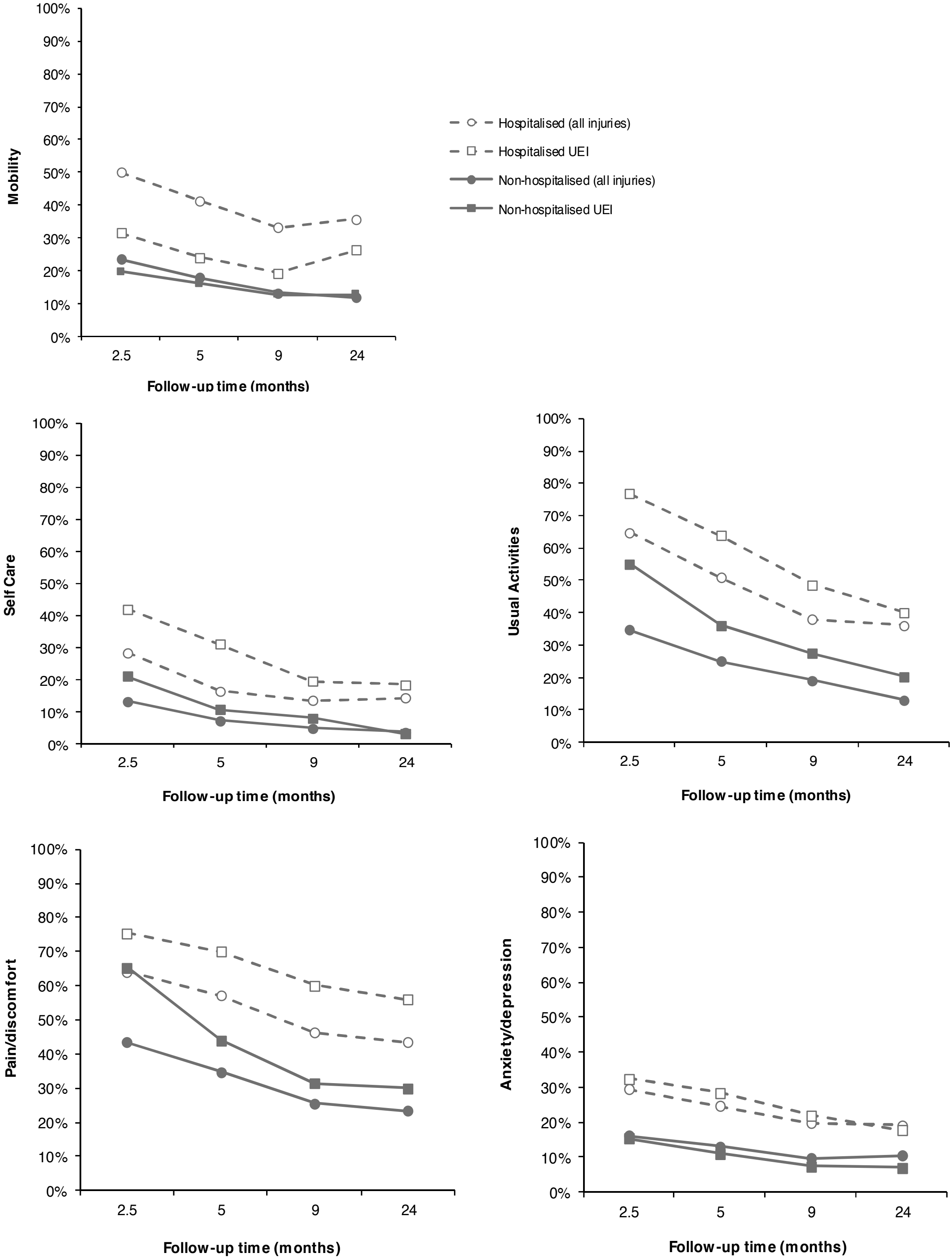
Multivariate regression analyses (R^2 = 0.41)

** per increasing year of age*

Pain and prevalence of limitations

Figure 2 shows the prevalence of limitations on each EQ-5D health domain for both UEI and injuries in general at 2.5, 5, 9 and 24 months after the injury. At all time points, the proportion of UEI patients with limitations on health domains self-care, usual activities and complaints of pain and/or discomfort was higher than in the group of all injuries. For non-hospitalized UEI patients, the substantial loss in HRQoL observed after 2.5 months was mainly due to limitations on health domains usual activities (55%) and pain and/or discomfort (65%). For hospitalized UEI patients, most patients experience limitations on health domains self-care, usual activities and pain and/or discomfort.

Figure 2 Proportion of patients reporting problems on each EQ-5D health domain (all injuries compared with UEI in hospitalized and non-hospitalized patients aged 18 years and older).



DISCUSSION

This study shows a considerable loss in HRQoL after UEI, for both non-hospitalized and hospitalized patients. For non-hospitalized UEI patients, a substantial loss in HRQoL was observed after 2.5 months, which later improved to the level of general population norms. For hospitalized UEI patients, HRQoL remained far below the general population norms. The more proximal upper extremity injuries, such as upper arm fractures, had a lower HRQoL and a slower recovery of HRQoL than distal injuries, such as hand/finger fractures. At all time points, the proportion of UEI patients with limitations on the health domains self-care, usual activities and complaints of pain/discomfort was higher than in the group of injuries in general. Female gender, higher age, low educational level, comorbidity, shoulder or upper arm injury, multiple injuries and hospitalization proved to be independent predictors for long-term loss in HRQoL.

The main strength of the present study is that we performed a comprehensive population-based study with prospectively collected data and a 2-year follow-up period. Previous studies considered either non-hospitalized or hospitalized patients, and/or were limited to one or a few hospitals and/or focused on a single specific subcategory of injury.[18-27] In the present study, we used nationwide data on both hospitalized patient care and data from a representative national sample of non-hospitalized patients. The Dutch Injury Surveillance System has a high level of completeness and validity, as shown in previous international studies.[28,31]

One limitation of the present study was the relatively low response rate to the first survey. This was mainly due to the use of postal surveys and limited possibilities to increase the response rates. Since background information on the non-respondents was available we could perform a non-response analysis using multivariate logistic regression, and adjust for determinants of non-response.[32] Another limitation is that patients were included based on the recorded primary diagnosis. In the case of multiple injuries, the most severe injury was recorded in the injury surveillance system, according to a hierarchical rule. This hierarchical rule gives priority to spinal cord and brain injury, lower extremity injury above upper extremity injury, and to fractures above other injuries.[1,4,29,32]

In addition, patients with minor injuries treated by their general practitioner were not recorded in the injury surveillance system. In the present study we used the EQ-5D, an internationally recommended measure to assess HRQoL in injury populations.[8-10] When we compare injured populations with general population norms, the potential difference in pre-injury health state between the general population and a population of trauma patients might be a reason for concern. However, previous studies have determined pre-injury health states in HRQoL after injury, showing better health states in injured populations.[35,36]

This is, to our best knowledge, the first study which compared specific upper extremity injuries to the total group injury patients in one comprehensive study with a 2-year follow-up. Our results are comparable with previous studies that considered specific subcategories of the most common injuries, such as distal radius fractures and proximal humerus fractures.[18-27] Clinical prospective studies on proximal humerus fractures from Olerud et al. showed a substantial deterioration in EQ-5D summary scores after proximal humerus fractures, which was of the same magnitude as that reported by patients with hip fractures.[21-23] In their patients with proximal humerus fractures, HRQoL during the 2-year follow-up was significantly lower than before the fracture, regardless of the primary treatment. Another prospective study on non-displaced proximal humerus fractures in women aged 50 years and older showed an average EQ-5D score of 0.64 six months after the injury.[27] Olerud et al. showed that the EQ-5D displayed good responsiveness in patients with proximal humeral fractures and that the EQ-5D can be recommended for use as a quality of life measure in patients with this injury.[37] Dolan et al. observed considerable loss in quality of life during the first 3 months after a wrist fracture, but a relatively fast recovery.[19] The EQ-5D has also been used by Hagino et al. in elderly women with hip, vertebral and wrist fractures; these authors showed that EQ-5D summary scores in patients with wrist fractures changed from 0.81 after 3 months to 0.88 after 12 months.[38] Ström et al. reported improvement in HRQoL from 0.83 after 4 months, 0.88 after 12 months and 0.90 after 18 months.[39]

This study may have implications for further research. In the last decades there has been a shift from using only clinical outcome assessment to the development and validation of patient-reported outcome measures. For example, in the field of joint replacement surgery [40,41] and several types of surgery (such as after hip fracture, groin hernia repair and varicose vein surgery), there is an increasing focus on patient-reported outcome measures to compare HRQoL before and after treatment.[42,43] In these fields, pain and HRQoL are often considered primary outcome measures. In that way, variations in provider performance on the separate EQ-5D dimensions can be analysed to improve health outcome.[44] In this study, proximal upper extremity injuries, such as upper arm fractures, showed more loss in HRQoL and slower recovery than distal injuries, such as hand/finger fractures. This study demonstrates that recovery from UEI takes a relatively long time and identifies predictors of outcome on these specific upper extremity injuries. Further clinical studies may focus on understanding how these predictors can be influenced in order to reduce time to recovery, and how surgery and post-surgical rehabilitation can decrease the burden as experienced by patients. Furthermore, data from patient-reported outcome measures as presented in this study can be used for cost-effectiveness analyses, benchmarking of hospitals and resource allocation. Despite its limitations, self-reported data from the patient's perspective provide additional insight into treatment outcome, and are needed to improve quality of care.

In conclusion, this study shows a considerable loss in HRQoL after UEI, for both non-hospitalized and hospitalized patients. For non-hospitalized UEI patients, a substantial loss in HRQoL was observed after 2.5 months, which later improved to the level of general population norms. For hospitalized UEI patients, HRQoL remained far below the general population norms. The impact of upper extremity injuries on HRQoL exceeds the health consequences of the group all injuries, mainly due to limitations on the health domains self-care, usual activities and complaints of pain/discomfort. Predictors for outcome on specific upper extremity injuries need to be further investigated in clinical studies, to understand how these differences affect patient-reported outcome measures and cost-effectiveness. Furthermore, clinicians should focus more on how the loss in HRQoL as experienced by their patients can be further reduced.

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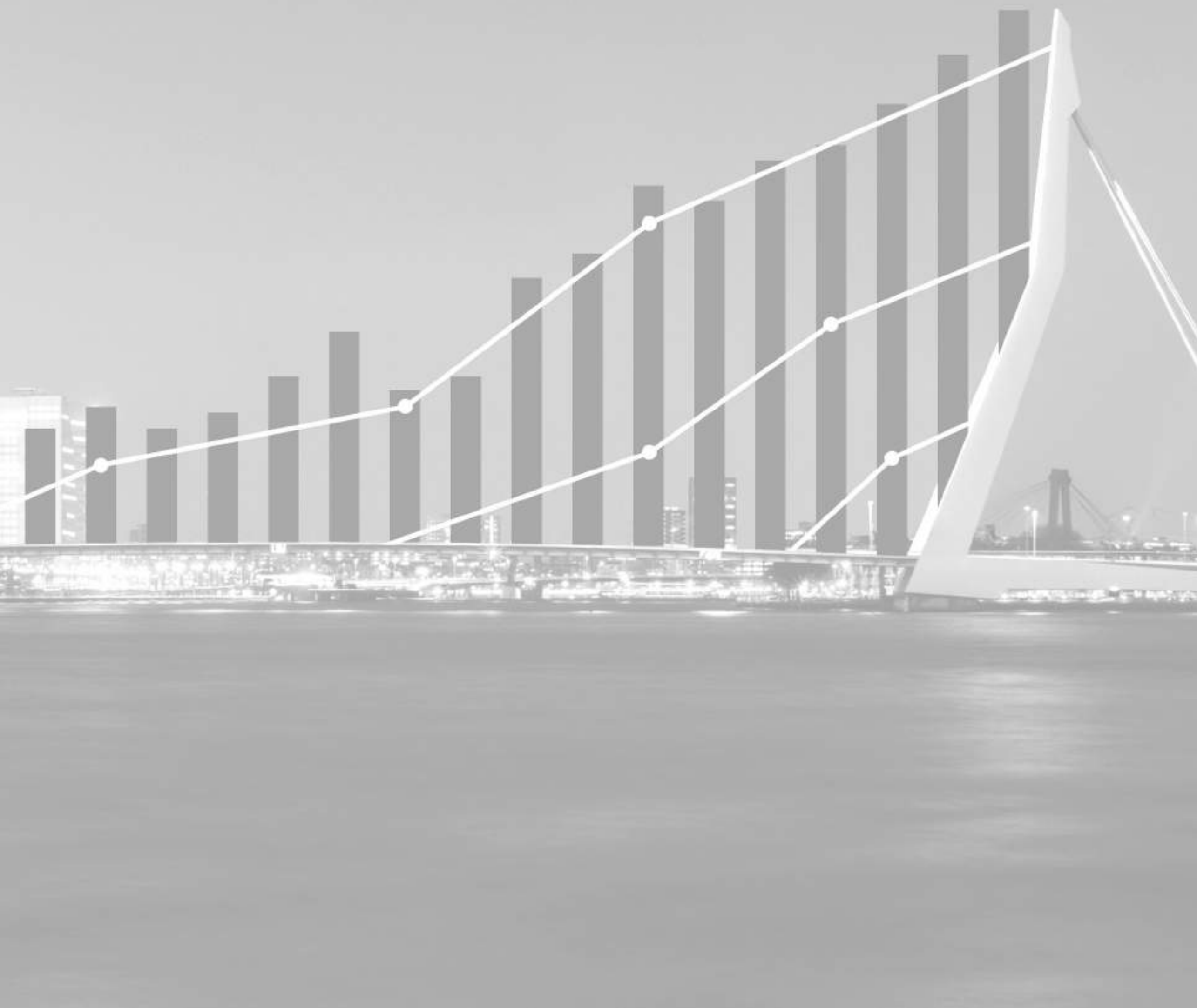
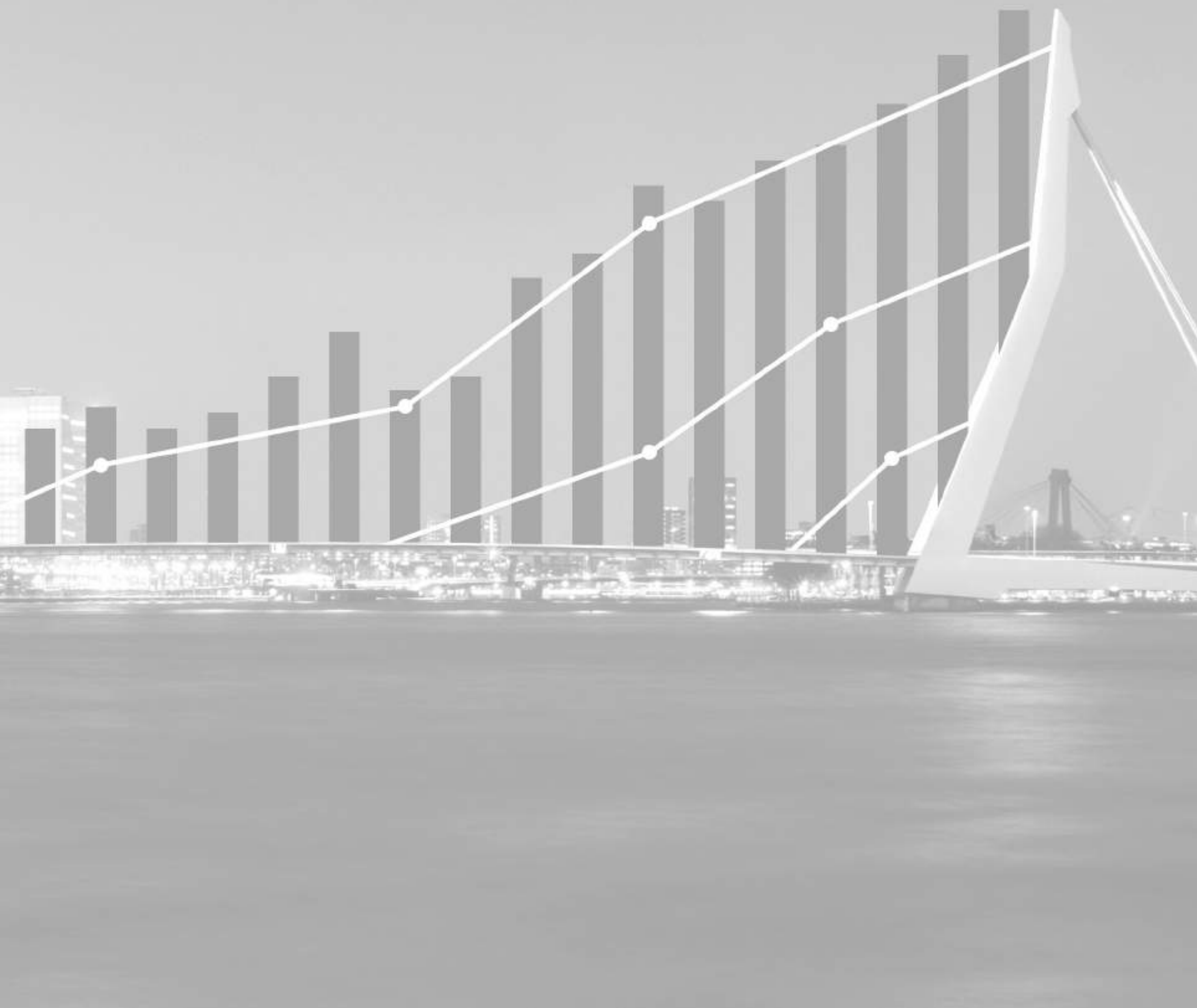
General discussion



Chapter 8

General Discussion



GENERAL DISCUSSION

This thesis addressed trends in the epidemiology of hand and wrist injuries in the Netherlands in part I. In part II, we quantified the impact of these injuries in terms of economic impact (healthcare costs and productivity costs) and health-related quality of life. In the present chapter, the main findings regarding the objectives as outlined in the general introduction will be presented and discussed in the context of recent literature. Subsequently, relative strengths and weaknesses of our methodological approach will be outlined and recommendations for the future will be made.

MAIN FINDINGS

PART I: TRENDS

Research question 1: Which trends and underlying causes can we identify in hand and wrist fractures in the Netherlands?

The purpose of part I of this thesis was to explore and evaluate epidemiological trends in hand and wrist injuries among different age categories, and to identify main contributors to these trends. Wrist fractures have their highest incidence in childhood and among older adults, and therefore specific attention was given to these populations-at-risk. In **chapter 2**, we showed that the incidence of wrist fractures in children and adolescents increased in boys and girls during our study period (1997-2009), with the strongest increase in the age category 10-14 years. This increase was mainly due to soccer injuries and gymnastics injuries occurring at school. In **chapter 3**, we further investigated the rise in soccer-related injuries in children and adolescents and showed an association between fracture rates in the oldest age category (15-18 years) and playing on artificial turf fields. In **chapter 4**, we showed decreasing incidence rates of wrist fractures in elderly females (aged 50 years and older), and relatively stable rates in males in the same time period. However, in spite of stabilizing or even decreasing incidence rates, healthcare consumption was increased due to higher admission rates and rising numbers of operations on hand and wrist injuries in the (very) elderly.

In general, the results of our studies on trends in hand and wrist fractures are comparable to other studies from the US, Europe and Asia.[1-10] A study from Finland showed an increasing incidence rate of paediatric distal forearm fractures treated in a hospital in the period 1996-2006.[2] Studies from the US showed that forearm fractures are the most common fracture type in the age category 10-14 years.[3] Another study from the US showed that the majority of injuries occurred during recreational activities and sports, and observed a rise in soccer-related wrist fractures.[4] Other contributing factors to increasing wrist fracture rates that have been suggested are increasing obesity prevalence and changing dietary habits resulting in altered bone metabolism.[11-15] But also environmental factors may play their role, such as the growing presence of artificial turf field in soccer. While the association between the rise of artificial turf fields and fracture rates in our (ecological) study does not allow causal inference, a previous study from the UK also showed an increased risk of sustaining a wrist fracture falling on artificial turf compared to natural grass.[16] On the other hand, the effect of artificial turf on injuries still remains open to discussion due to inconsistent results from previous cohort studies.[17] An alternative explanation for the increased in soccer related fractures may be a change in play behaviour, such as foul play.[18,19] However, in our study, no independent effect of physical contact could be demonstrated.

Decreasing incidences of wrist fractures among the elderly have also been reported in studies from other countries, including the US and Canada.[20,21] Similar factors which contribute to a decrease in wrist fractures may also contribute to the recent observed decrease in hip fractures. Hormone replacement therapy, for example, has been shown to increase bone mineral density and to reduce the incidence of hip fractures.[22,23] On the contrary, obesity is increasing in Western societies and may be associated with a reduced fracture risk in older adults. However, the relationship between fat mass and bone density varies with age, and more advanced imaging techniques are needed to clarify the relation between fat and bone with increasing age.[11] Smoking has also been associated with an increased risk of fracture[24] however, stable fracture rates in males in this study cannot fully be explained by declining smoking rates. Hospitalization rates strongly increased in both males and females in the same time-frame, especially for plate and screw fixation techniques in all age categories. A few previous studies reported on trends in wrist fracture hospitalization rates, varying from a decreasing rate in France, to increasing rates in Australia and Switzerland.[25-28] Increasing hospitalization rates might be explained by changes in surgical policies for treatment of wrist fractures. For example, previous studies from the US and Finland showed a trend towards more operative treatment[29-33], and the same trends towards increased use of surgical stabilisation of forearm fractures have been observed in children.[14,34,35] The reasons for these trends are multifactorial, including societal expectations of an optimal result, and reduced hospital stay which results in reduced costs.[14] However, the increasing choice for surgical treatment in children and adults is not yet fully supported by clinical evidence and deserves further high quality studies.[36-40]

PART II: SOCIETAL CONSEQUENCES

Research question 2: What is the economic impact of hand and wrist injuries, divided by type of injury and external cause?

In **chapter 5**, we quantified the total healthcare costs and productivity costs of hand and wrist injuries, and showed that at population level these injuries are one of the most expensive injury types. The majority of costs were attributable to productivity costs, and hand and finger fractures were the most expensive subgroup, due to high loss of productivity in the working-age population. Subsequently, in **chapter 6**, we showed that the majority of costs due to non-trivial hand and wrist injuries (i.e. hand fractures, wrist fractures and complex soft-tissue injuries) in the working population were caused by accidents at home and bicycle injuries.

A previous study from the Netherlands showed that the costs due to injuries are comparable with those of cancer and stroke.[41,42] Fractures had the highest costs of all injuries, due to possible admissions, longer rehabilitation, plaster treatment, diagnostic imaging and surgery. The proportion of productivity cost in total costs in our study is comparable or even lower compared with those found in previous clinical studies from Sweden, which reported on the costs of nerve or tendon injuries with productivity costs varying from 55-87% of total costs.[43-45] Differences might be due to different methods used to obtain data, case mix, different costs elements, time periods or different healthcare and social security systems. For example, a study from the US showed that patients with hand and wrist disorders receiving work loss compensation had higher healthcare costs and a longer time-off-work work compared to patients with standard insurance.[46] A clinical study from Sweden, analysing costs of serious hand and arm injuries, showed that work-related injuries represented the highest costs and had a 69% higher risk of hospitalization compared to leisure-time related injuries.[47] However, in our studies, home-related injuries represented the majority of costs, followed by traffic- and work-related injuries. This might partly be explained by selection and referral bias, especially differences between the patient population in the clinical study and our population-based survey. The patients in the clinical study were referred to the department of hand surgery, and therefore serious injuries (such as work-related injuries) could be overrepresented in their study sample compared to our study. The strength of our observational studies is that we gain insight in the impact of hand and wrist injuries in the general population.

Research question 3: What is the impact of hand and wrist injuries on health-related quality of life?

In **chapter 7**, we used the EQ-5D questionnaire to quantify the impact of upper extremity injuries (UEI) on Health-Related Quality of Life (HRQoL) in adult patients. The impact of upper extremity injuries on HRQoL exceeds the health consequences of the general injury population, for both hospitalized and non-hospitalized patients, mainly due to limitations on the health domains self-care, usual activities and complaints of pain/discomfort. Female gender, higher age, low educational level, comorbidity, shoulder or upper arm injury, multiple injuries and hospitalization were independent predictors for long-term loss in HRQoL.

Previous studies on the HRQoL after upper extremity injuries, and hand and wrist injuries in particular, are scarce. So far, the results of our population-based study with a two-year follow-up are in line with the few previous clinical studies that considered specific upper extremity injuries, such as distal radius fractures or proximal humerus fractures.[48-50] The EQ-5D has been used in elderly women with wrist fractures, and showed improvement in EQ-5D summary score from 0.81 at three months to 0.83-0.89 at one year after the injury.[51-53] A Dutch validation study of a quality of life questionnaire for patients with wrist fractures reported an increase from 0.76 at three months, to 0.80 after one year in a matched case control study.[54] The presence of upper extremity injuries substantially reduces health-related quality of life on both short and long term, and future HRQoL studies may provide additional insight into treatment outcome.

STRENGHTS AND LIMITATIONS

Strengths

A major strength of our studies is that we had access to high-quality population database systems: i.e. the Dutch Injury Surveillance System and the National Hospital Discharge Registry. International studies showed that the Dutch Injury Surveillance System has a high level of completeness and validity.[55,56] The participating hospitals in the Dutch Injury Surveillance System are scattered over the country, to avoid possible selection biases due to differences between rural and urban areas.[57] The National Hospital Discharge Registry has almost full national coverage, and uses the same uniform classification and coding system (ICD, the International Classification of Diseases) over time.[58] In general, the accuracy and completeness of the database systems depends on the accuracy of the clinical information and diagnosis as written in the medical records; subsequently, registry staff will code the discharge diagnosis into the hospital information system (ZIS). To minimise coding errors and variation, official trauma registry staff translates these information into ICD codes. Despite a study from the US on the inaccuracy of hospital trauma registries[59], a validation study in the Netherlands reported high accuracy and completeness of the coded injury data in our data systems (91% correctly coded and 9% missing data).[60]

A second strength of our studies is that the fractures we analysed are part of the selected radiological verifiable fractures. International experts have recommended these fracture types for comparative research and trend analyses, because in the vast majority of cases these patients will visit the emergency department (ED) and the fractures will be confirmed by imaging.[56] By using these high quality data systems and our case selection we were able to conduct valid trend analyses over a long time-interval.

Thirdly, we used the Burden of Injury model to estimate the costs of injuries, which has been used in several studies.[42,61-63] This economic model is based on incidence data from the previously described high-quality data systems, and allows comprehensive follow-up on both healthcare costs and productivity costs. In addition, information on the injury causes and mechanisms is collected, which is important for prevention strategies.

Methodological limitations

One of the limitations of a population-based database of this scale is restricted number of available clinical variables, such as co-morbidity, injury severity, or fracture type. For example, by using non-specific fracture codes, such as wrist fracture, the exact distribution between distal radius fractures and scaphoid fractures is not known. As a result, our study cannot test whether the incidence of scaphoid fracture diagnosis has increased during the last decade due to the use of advanced imaging modalities such as MRI or CT, which can confirm a scaphoid fracture at an earlier stage compared to conventional X-ray.[64] Another reason for possible underestimation of the incidence, is that patients were selected based on the registered primary diagnosis. In cases with multiple injuries, the most severe injury was given priority by a previously described algorithm.[65] For example, multitrauma patients, with wrist fractures and a more severe injury (e.g. intracranial injury) have been excluded from the analyses, which may have led to an underestimation of the incidence.

Secondly, there are limitations related to the designs we used in our studies. In our observational studies, we were able to identify possible risk factors and trends. For example, we described increasing fracture rates in children that coincide with an increasing number of artificial turf in the same time period. However, no causal inference can be shown from these observation studies; therefore, our population-based studies can be a basis for future additional studies, to enlighten this possible relation between upper extremity fractures and artificial turf.

Thirdly, some of the limitations are related to the Burden of Injury model, as previously described.[61] In this incidence-based model, we only included patients who attended the emergency department; however, most patients treated outside the hospital (for example treated by the general practitioner) have minor injuries. For this reason, and assuming that the cost per patient is comparable to the costs per patient with minor injuries treated at the ED, we calculated that this will lead to only a slight underestimation of the costs. Another limitation of this model is that the follow-up period was restricted to 9 months after the injury, which would have led to an underestimation of the costs when problems persevere.

IMPLICATIONS AND FUTURE DIRECTIVES

The results of the present thesis has a number of important implications for further research and policies in both public health and clinical medicine.

Prevention strategies

Active injury surveillance and prevention strategies for children and adolescents are required, and prevention initiatives should be targeted toward high-risk individuals such as young soccer players, to help to reduce the incidence of hand and wrist injuries. Effective strategies could have a high impact on both direct medical costs and societal costs. Estimates on the incidence provide important information for priorities in intervention strategies, and trend information can provide a crude estimation of effects of identifiable changes in determinants of injuries, and changes in health practice and prevention strategies.[66] Further injury surveillance would be improved by the inclusion of additional questions, such as the type of playground where the injury took place (i.e. on third-generation artificial turf fields, versus natural grass), or the number of injuries per 1000 hours of exposure.[67]

For older persons, research should focus on primary prevention of falls, such as fall prevention programmes and on the underlying causes of falls. Previous studies from the Netherlands showed an increased fall risk in older adults due to deterioration in balance control.[68,69] In addition, rehabilitation after a wrist fracture - such as physical therapy for gait and balance training - may result in improved clinical outcomes.[70] Prevention strategies should be targeted at the major contributing causes, that are mainly related to activities at home (such as falls, and contact with an object) and accidents at the road (such as cycling).

Clicinal studies and cost-effectiveness

Currently, there is a wide variation in treatment of wrist fractures, and distal radius fractures in particular.[30] A study from Australia showed that operative treatment was more likely to be chosen by junior surgeons and by surgeons specialising in the affected body region (i.e., shoulder surgeons for clavicle and humerus fractures, and hand surgeons for scaphoid and distal radius fractures).[71] Therefore, there is a need for high quality evidence for the surgical management of distal radius fractures in both children and older adults, compared to cast immobilisation, including long term outcome, complications and cost-effectiveness. We need large multicenter clinical trials, such as the WRIST (Wrist and Radius Injury Study Group) and ORCHID (Open Reduction and internal fixation versus Casting for highly Comminuted and Intra-articular fractures of the Distal radius), with long-term follow-up, to accurately delineate the best treatment options for the individual patient at all ages.[72-74] In addition, clinical research on surgical and rehabilitation interventions of hand and wrist injuries that aim to lower the time off work may have a large economic potential, for example minimal invasive surgery techniques, or early active mobilisation therapy. It has been shown that a patient-oriented rehabilitation-programme after hand surgery reduces time of work and that early dynamic motion after tendon transfers can shorten rehabilitation time.[75,76]

Patient Reported Outcome Measures (PROM)

During the past decades there has been a shift from using only clinical outcome measures to the development and validation of patient-reported outcome measures, such as the EQ-5D. For example, in the field of joint replacement surgery, there is an increasing focus on patient-reported outcome measures to compare HRQoL pre- and post-operative scores.[77] In these and other surgical fields, pain and HRQoL are often considered primary outcome measures. In that way, variations on the separate EQ-5D dimensions can be analyzed to improve health outcome.[78] Further clinical studies may focus on understanding how these predictors can be influenced in order to reduce time to recovery, and how surgery and rehabilitation can decrease the burden as experienced by patients. Furthermore, data from patient-reported outcome measures can be used for cost-effectiveness analyses, benchmarking of hospitals and resource allocation. Despite its limitations, data from the patient’s perspective, such as the EQ-5D, may provide additional insight into treatment outcome, and are needed to improve the quality of care of patients with hand and wrist injuries.

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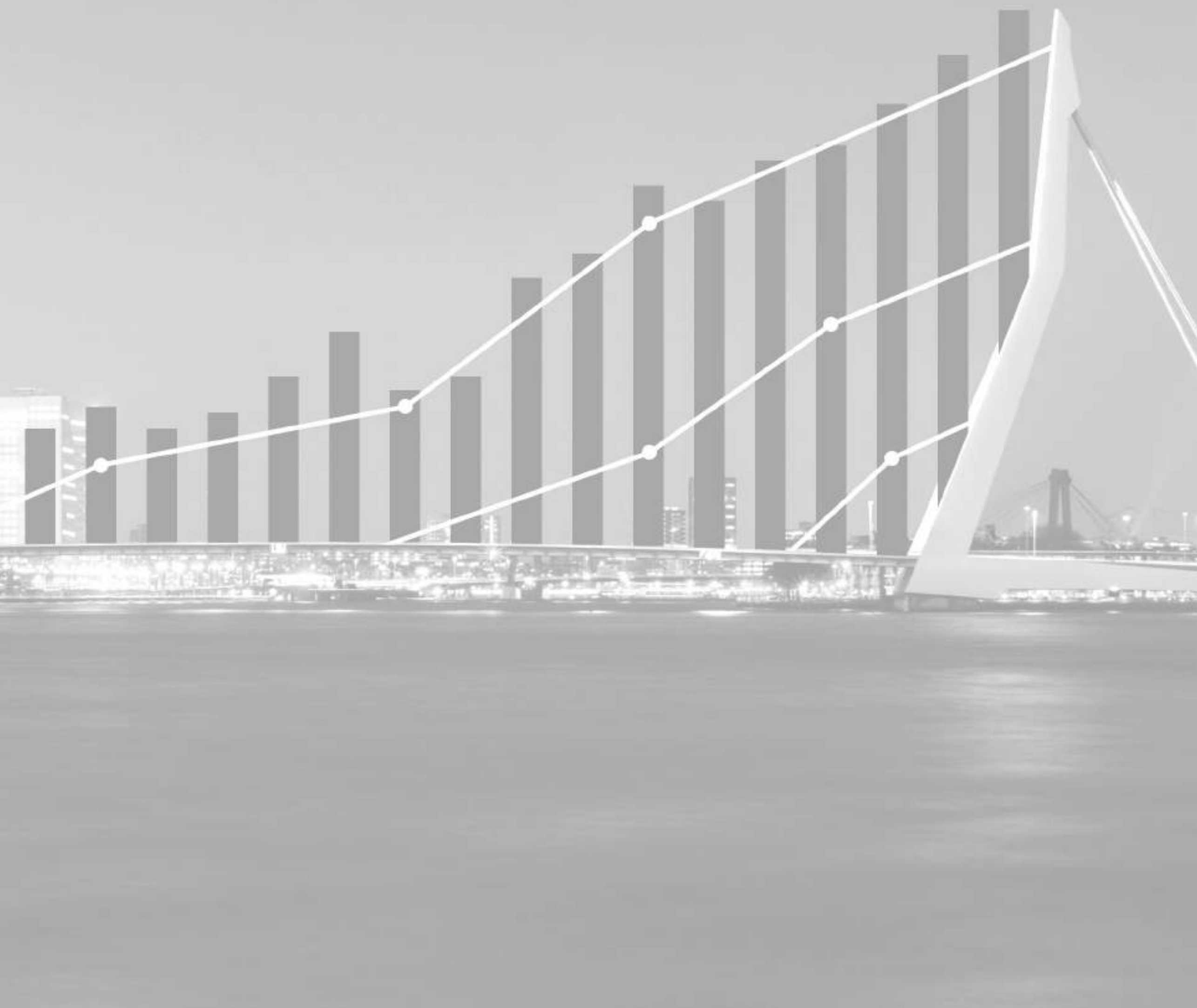
Chapter 9

Summary
Samenvatting
Acknowledgements
About the Author
List of Publications
PhD Portfolio



Summary

Upper extremity injuries, and hand and wrist injuries in particular, represent a substantial part of all injuries at the emergency department and represent a significant economic burden to society. In this thesis, we describe trends in injuries among children & adolescents, adults and elderly (part I), and quantify the impact on Dutch society in terms of healthcare costs, productivity costs and health-related quality of life (part II).

After an introduction in **chapter 1,** in **chapter 2**, we examine recent population-based trends in incidence and causes of wrist fractures in children and adolescents. Data were obtained from the Dutch Injury Surveillance System and from the National Hospital Discharge Registry. Incidence rates of wrist fractures per 100,000 persons were calculated for each year between 1997 and 2009. Trends for children and adolescents aged 5-9, 10-14, and 15-19 years were analysed separately for boys and girls. During the study period, incidence rates increased significantly in boys and girls aged 5-9 and 10-14 years, with the strongest increase in the age group 10-14 years. The observed increases were mainly due to increased incidence rates during soccer and gymnastics at school. Subsequently, in **chapter 3**, we analysed age-specific trends in hospital-treated upper extremity fractures (UEF) among boys playing soccer in the Netherlands and explored associated soccer-related factors. Poisson's regression was used to explore the association of UEF with the number of artificial turf fields and the number of injuries by physical contact. UEF rates increased significantly by 19% in boys 5-10 years, 73% in boys 11-14 years and 39% in boys 15-18 years old. The number of artificial turf fields showed an independent association with UEF in the oldest boys, suggesting that playing on artificial grass could be harmful. In **chapter 4**, trends in incidence, hospitalization and operative treatment of wrist fractures were determined in patients of 50 years and older. In females, the age-standardized incidence rate of wrist fractures decreased from 497 per 100,000 persons (95%CI, 472-522) in 1997 to 445 (423-467) in 2009 (*P* for trend <.001). In males, no significant trends were observed in the same time period. Hospitalization rates increased from 30 (28-32) in 1997 to 79.0 (75-83) in 2009 in women (*P*<.001), and from 6 (6.0-7.0) to 18 (17-20) in men

($P<.001$). There was a strong increase in operative treatment of distal radius fractures, especially due to plate fixation techniques in all age groups. Incidence rates of wrist fractures decreased in women and remained stable in men, but hospitalization rates strongly increased due to a steep rise in operative treatments.

In part II, we determined the impact of hand and wrist injuries in terms of healthcare costs, productivity costs and health-related quality of life. In **chapter 5**, we quantified the economic impact of hand and wrist injuries, in terms of healthcare costs and productivity costs, and compared them to other injury groups in a nationwide study. Data were retrieved from the Dutch Injury Surveillance System, from the National Hospital Discharge Registry and from a patient follow-up survey conducted between 2003 and 2007. An incidence-based cost model was used to estimate healthcare costs of injuries. Follow-up data on return to work rates were incorporated for estimating the productivity costs. Hand and wrist injuries annually account for US $740 million and rank first in the order of most expensive injury types, before knee- and lower leg fractures (US $562 million), hip fractures (US $532 million) and skull-brain injury (US $355 million). Productivity costs contributed more (56%) than direct healthcare costs to the total costs of hand and wrist injuries. Within the overall group of hand and wrist injuries, hand and finger fractures are the most expensive group (US $278 million), largely due to high production costs in the age-category 20-64 years. Hand and wrist injuries constitute not only a substantial part of all treated injuries, but also represent a considerable economic burden.

Subsequently, in **chapter 6**, we explored the causes and costs of non-trivial hand and wrist injuries (i.e., hand fractures, wrist fractures and complex soft-tissue injuries) in working-age adults (age 20-64 years) in order to identify target areas for prevention. Total costs were calculated by external cause, subdivided in their main categories (home, sports, work, traffic and violence) and their most important subclasses. Total costs of these injuries in the Netherlands were US $410 million per year, of which 75% (US $307 million) productivity costs. Males represented 66% (US $271 million) of the total costs. Within the male group, the group 35-49 years had the highest contribution to total costs (US $112 million), as well as the highest costs per case (US $10675). While work-related injuries showed the highest costs per case (US $11797), only 25% of the total costs were work-related. The top five causes in terms of total costs were: accidents at home (falls 23%, contact with an object 17%), traffic (cycling 9%) and work (industrial work 4%, and construction work 4%). To reduce the costs to society, prevention initiatives may be targeted at the major contributing causes, that are mainly related to activities at home (falls, contact with an object) and road traffic accidents (cycling).

In **chapter 7**, we examined the impact of upper extremity injuries (UEI) on health-related quality of life in adult patients. We compared the quality of life scores after UEI with those of patients with other types of injuries and with the general population, to establish recovery patterns of different types of UEI and determine predictors for suboptimal outcome. Data were obtained from the Dutch Injury Surveillance System, from the National Hospital Discharge Registry, and from a patient follow-up survey. We included 608 patients (aged 18 years and older) with an UEI. Main outcome measure was health-related quality of life (according to the Euro-Qol-5D, EQ-5D) measured at 2.5, 5, 9 and 24 months after the UEI. Predictors for suboptimal outcome were examined by multivariate linear regression analyses. For non-hospitalized patients, a substantial loss in health-related quality of life was observed after 2.5 months, which improved to the level of the general population norms by 24 months. For hospitalized patients, health-related quality of life improved from 2.5 months to 24 months, but remained far below population norms. At all time points, the proportion of UEI patients with limitations on the health domains self-care, usual activities and complaints of pain or discomfort was higher than in the group of all injuries. Female gender, higher age, low educational level, comorbidity, shoulder or upper arm injury, multiple injuries and hospitalization are independent predictors for long-term loss in health-related quality of life. The presence of upper extremity injuries substantially reduces health-related quality of life on the short and long term, mainly due to limitations on the health domains self-care, usual activities and complaints of pain or discomfort.

Nederlandse samenvatting

Letsels van de bovenste extremiteit, en hand- en polsletsels in het bijzonder, vertegenwoordigen een aanzienlijk aandeel van alle letsels die gezien worden op de spoedeisende hulp, en vormen daarmee ook een groot aandeel van de maatschappelijke kosten. In dit proefschrift beschrijven we trends in letsels in kinderen, adolescenten, volwassenen en ouderen (deel I), en kwantificeren we de maatschappelijke impact van deze letsels in termen van medische kosten, verzuimkosten en verlies in kwaliteit van leven (deel II).

Na de introductie in **hoofdstuk 1**, onderzoeken we in **hoofdstuk 2** trends in incidentie en oorzaken van polsfracturen in kinderen en adolescenten in een populatie-brede studie. De data werden verkregen uit het Nederlandse Letsel Informatie Systeem (LIS) alsmede uit de Landelijke Medische Registratie (LMR). Incidenties van polsfracturen werden berekend voor elk jaar tussen 1997 en 2009, en trends voor kinderen en adolescenten in de leeftijdsgroepen 5-9, 10-14 en 15-19 jaar werden geanalyseerd. Gedurende de studieperiode was er een significante stijging in incidentie van polsfracturen bij jongens en meisjes in de leeftijdsgroepen 5-9 en 10-14 jaar, met de sterkste stijging in de groepen 10-14 jarigen. De belangrijkste oorzaken voor deze stijging zijn veldvoetbal en gymles op school. In **hoofdstuk 3** analyseerden we leeftijd-specifieke trends in fracturen van de bovenste extremiteit in jonge mannelijke voetballers, en onderzochten we de associatie met voetbal-gerelateerde factoren. Poisson regressie werd gebruikt om de associatie te onderzoeken tussen fracturen van de bovenste extremiteit enerzijds, en het aantal kunstgrasvelden en het aantal letsels door fysiek contact anderzijds. Het aantal fracturen per 1000 spelers nam met 19% toe in de groep 5-10 jarigen, met 73% in de groep 11-14 jarigen en met 39% in de groep 15-18 jarigen. Het aantal kunstgrasvelden liet een onafhankelijke associatie zien met fracturen van de bovenste extremiteit in de oudste leeftijdsgroep, hetgeen er op zou kunnen wijzen dat spelen op kunstgras het risico op fracturen kan vergroten. In **hoofdstuk 4** beschrijven we trends in incidentie, ziekenhuis opnames en operatieve behandelingen van polsfracturen in patiënten van 50 jaar en ouder. In de groep vrouwen daalde de incidentie van 497 per 100.000 personen (95%CI, 472-522) in 1997 naar 445 (423-467) in 2009 (p voor trend <.001). In de groep mannen werden geen significante trends waargenomen in dezelfde tijdsperiode. Het aantal ziekenhuis opnames nam toe van 30 per 100.000 personen (28-32) in 1997 naar 79 (75-83) in 2009 in vrouwen (P<.001) en van 6 (6.0-7.0) naar 18 (17-20) bij de mannen (P<0.001). Er was een sterke toename in het aantal operatieve behandelingen van distale radius fracturen, met name door plaatfixatie technieken in alle leeftijdsgroepen. De incidentie van polsfracturen nam af bij de vrouwen en bleef stabiel bij de mannen, echter het aantal ziekenhuisopnames nam sterk toe door de toename in het aantal operatieve behandelingen.

In deel II kwantificeerden we de impact van hand- en polsletsels in termen van medische kosten, verzuimkosten en kwaliteit van leven. In **hoofdstuk 5**, kwantificeerden we de economische impact van hand en polsletsels, en vergeleken we deze met andere letselgroepen in een populatie-brede studie. De data werden verkregen uit het Nederlandse Letsel Informatie Systeem (LIS), uit de Landelijke Medische Registratie (LMR), alsmede uit een patiënten vragenlijst tussen 2003 en 2007. We gebruikten het letsellast-model om de medische kosten te schatten. Follow-up data over het arbeidsverzuim werden verwerkt om de verzuimkosten te berekenen. Hand- en polsletsels kosten jaarlijks tot 740 miljoen dollar en vormen daarmee een van de duurste letsels, duurder dan bijvoorbeeld knie- en onderbeenfracturen (562 miljoen dollar), heupfracturen (532 miljoen dollar) en schedel-hersenletsel (355 miljoen dollar). Verzuimkosten droegen meer bij (56%) aan de totale kosten dan de medische kosten. Binnen de groep hand- en polsletsels waren de hand- en vingerfracturen verantwoordelijk voor de meeste kosten (278 miljoen dollar), met name door de hoge verzuimkosten in de groep 20-64 jarigen. Daarmee vormen hand- en polsletsels niet alleen een substantieel aandeel van het aantal letsels op de spoedeisende hulp, ze vertegenwoordigen ook een aanzienlijk aandeel van de maatschappelijke kosten.

Vervolgens, in **hoofdstuk 6**, onderzochten we de oorzaken van de groep niet-triviale hand- en polsletsels (dat zijn: handfracturen, polsfracturen en complexe wekedelenletsels) in de beroepsbevolking (in de leeftijd van 20-64 jaar) om de aandacht voor preventie te optimaliseren. De totale kosten werden berekend per oorzaakgroep (thuis, sport, werk, verkeer en geweld), en verder onderverdeeld in de belangrijkste subcategorieën. De totale kosten van deze letsels in Nederland was 410 miljoen dollar per jaar, waarvan 75% (307 miljoen dollar) verzuimkosten. Mannen vertegenwoordigden 66% van de totale kosten, en de groep mannen van 35-49 jaar had hierbij het grootste aandeel in de kosten (112 miljoen dollar), alsmede de hoogste kosten-per-case (10675 dollar). Werk-gerelateerde letsels gaven de hoogste kosten-per-case (11797 dollar). Echter, slechts 25% van de totale kosten waren werk-gerelateerd. De top 5 oorzaken in totale kosten waren: ongevallen thuis (vallen 23%, contact met een object 17%), verkeer (fietsen 9%) en werk (industrie werk 4% en constructie werk 4%). Om de maatschappelijke kosten te verlagen, zouden preventie initiatieven zich moeten richten op de belangrijkste oorzaken, die met name gerelateerd zijn aan activiteiten in en om het huis (vallen, contact met een object) en ongevallen op de weg (fietsen).

In **hoofdstuk 7** onderzochten we de impact van bovenste extremiteitsletsels op de kwaliteit van leven in volwassen patiënten. We vergeleken deze kwaliteit van leven scores met die van slachtoffers met andere letsels en met de algemene populatie, om op die manier herstelpatronen in kaart te brengen en voorspellers voor een suboptimale uitkomst te bepalen. De data werden verkregen uit het Nederlandse Letsel Informatie Systeem (LIS), uit de Landelijke Medische Registratie (LMR), alsmede uit een vragenlijst voor patiënten. Er werden 608 patiënten van 18 jaar en ouder met een letsel aan de bovenste extremiteit geïncludeerd. De primaire uitkomstmaat was de kwaliteit van leven (volgens de Euro-Qol-5D, EQ-5D), gemeten op 2.5, 5, 9 en 24 maanden na letsel. Voorspellers voor suboptimale uitkomst werden onderzocht met multivariate lineaire regressie analyses. Voor de groep niet-opgenomen patiënten werd een substantieel verlies aan kwaliteit van leven gescoord gedurende de eerste 2.5 maand, welke verbeterde tot het niveau van de algemene populatie na 24 maanden. Voor de groep opgenomen patiënten verbeterde de kwaliteit van leven in de periode van 2.5 tot 24 maanden na het letsel, echter de scores bleven ver achter bij de algemene populatie norm. Op alle tijdspunten was het aandeel patiënten met letsel van de bovenste extremiteit met beperkingen op de domeinen zelfzorg, gebruikelijke activiteiten en pijnklachten of ongemak groter dan in de groep van alle letsels samen. Vrouwelijk geslacht, hoge leeftijd, laag opleidingsniveau, comorbiditeit, schouder- of bovenarmletsel, multipele letsels en opname waren onafhankelijke voorspellers voor langdurig verlies aan kwaliteit van leven. We concluderen hieruit dat letsels van de bovenste extremiteit een substantieel effect op de kwaliteit van leven van patiënten hebben, op zowel de korte als de lange termijn, met name door beperkingen op de domeinen zelf zorg, gebruikelijke activiteiten en pijnklachten of ongemak.

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Den Haag, 16 november 2016

Dennis

About the Author

Dennis de Putter was born on March 9th, 1982 in Terneuzen, the Netherlands. In 2000 he graduated from the Zeldenrust-Steelant College in Terneuzen. He moved to Delft and started his studies in Aerospace Engineering (Delft University of Technology) and finished his first year. In 2001, he started Medicine (Erasmus University, Rotterdam). After an internship in Tanzania in 2008, he finished Medicine and started his PhD-study at the Department of Plastic, Reconstructive and Hand Surgery (prof.dr. S.E.R. Hovius) and the Department of Public Health (prof.dr.ir. A. Burdorf) at the Erasmus Medical Center. Between 2009 and 2011 he did clinical residencies at the Departments of General Surgery in Haga Hospital in The Hague (dr. J.W.S. Merkus) and Reinier de Graaf Hospital in Delft (dr. M. van der Elst), and worked as an Insurance Physician (UWV, The Hague). In 2012 he started his residency at the Department of Radiology in Erasmus MC (prof.dr. G.P. Krestin, dr. W. van Lankeren) and Maasstad Hospital (dr. D. Vroegindeweij), and will further focus on musculoskeletal imaging.

List of Publications

de Putter CE, van Beeck EF, Looman CW, Toet H, Hovius SER, Selles RW. Trends in wrist fractures in children and adolescents, 1997-2009. J Hand Surg Am 2011 Nov;36(11):1810-1815.

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PhD Portfolio

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	ECTS
General academic skills	
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Course Methodology of Patient Oriented Research	2.0
Course Research Integrity	2.0
Specific research courses	
Introduction to Clinical Research	2.0
Biostatistics for Clinicians	2.0
Classical methods for data-analysis	2.0
Principles of Epidemiological data-analysis	2.0
Presentations, (inter)national conferences or accepted abstracts	
Oral presentation NVPC	2.0
Various presentations at research seminars and symposia at Erasmus MC, Reinier de Graaf Hospital and Haga Hospital	4.0
FESSH Hand Congress Oslo 2011	1.0
FESSH Hand Congress Antwerp 2012	1.0
IFFSH-IFSHT Congress New Delhi 2013	1.0
Musculoskeletal Radiologists meeting Utrecht	1.0
Seminars and Workshops	
Seminar Traumatic Injury, Erasmus MC	1.0
Wound Congress Rotterdam	1.0
Course Health Physics for Radiologists level 3M	4.0
Radiology National Congress	1.0

Radiology Sandwich Courses	4.0
Musculoskeletal Ultrasound Course Antwerp	1.0
Musculoskeletal late summer CT and MRI course Heerlen	1.0
TIAS-Medical Business Education Summer Academy	2.0

Medical skills

Advanced Traumatic Life Support	4.0
Resident General Surgery Haga Hospital and Reinier de Graaf Hospital	20.0
Insurance physician UWV The Hague	5.0

Teaching activities

Second and third year education	1.0
Traumatic injury to the hand	1.0
Tendon and nerve regeneration	1.0
Research presentations	1.0