Safety promotion and injury surveillance with special focus on young people´s club sports

Challenges and possibilities

Stefan Backe

Faculty of Health, Science and Technology

Public Health Science

DISSERTATION | Karlstad University Studies | 2014:61

Safety promotion and injury surveillance with special focus on young people´s club sports

Challenges and possibilities

Stefan Backe

DISSERTATION | Karlstad University Studies | 2014:61

Safety promotion and injury surveillance with special focus on young people´s club sports - Challenges and possibilities

Stefan Backe

DISSERTATION

Karlstad University Studies | 2014:61

urn:nbn:se:kau:diva-34429

ISSN 1403-8099

ISBN 978-91-7063-601-1

© The author

Distribution:
Karlstad University
Faculty of Health, Science and Technology
Department of Social and Psychological Studies
SE-651 88 Karlstad, Sweden
+46 54 700 10 00

Print: Universitetstryckeriet, Karlstad 2014

WWW.KAU.SE

PREFACE

One might take for granted that participating in sport should be fun and stimulating, but recurrent alarming reports in media about different kinds of problems in youth sports testify that it is unfortunately not the case in all situations. My first organised steps into sports occurred on the ice rink to play bandy in 1974. As I remember, in the beginning, it felt exciting and also stimulating when my team and I won competitions. Unfortunately this feeling turned into a constant worry about losing upcoming matches. I remember that the anxiety was manifested in a fear of being inadequate as defender and that my mistakes could mean a goal scored by the opposing team. This fear finally resulted with my decision to stop playing bandy. I continued with sports, though, doing sailing for some years, along with playing football in high school. I liked to play football but disliked always having to take a position as a defender. On several occasions when I had the chance to play along with the best strikers of my age, I took the role as a midfielder. At this position I often managed to pass for goal to the delight of our team. My teacher's point of view on the other hand was shown in comments like the following: "Well done but you cannot leave your position as defender in that way." These comments led to my lack of interest in organised sports for a very long time. Instead, I opted for spontaneous exercise in the form of running, floorball (innebandy), and badminton play.

Through my work as assistant nurse during the nineties in the emergency room at the hospital in Helsingborg city and through my work as a volunteer paramedic, my interest in sports medicine grew. I began to wonder why healthcare devoted so little time to investigate the risks of injury and injury patterns in connection with sports, particularly sports involving young participants, and why sports clubs so rarely asked for information about the events behind the injury incidents that occurred in connection with a sport activity, i.e., motor-cross racing. Other sport-related issues such as the first aid knowledge of athletes also attracted my interest.

During the same time my interest in injury registration and injury prevention deepened, which subsequently resulted in an assignment from Nacka Municipality in 2000, to develop a certification model for Safe Sports which could support sports clubs in their work to prevent injuries. Two years later I finished a master thesis on sports injuries in young people and was awarded a Masters in Medical Science with a major in Public Health.

The most interesting findings from these two works were that sports clubs in general had poor awareness regarding sports injuries. Results from the injury surveillance study, which I built upon in my master thesis, showed that every third sports-related injury (331 of 1009) occurred in the age group of players between 15-24 years. The girls suffered most injuries while playing football and handball, while for the boys it was football, ice hockey and floorball. Furthermore, falls comprised 40 % of all external events leading to sports injuries in girls and 24 % in boys, with the second leading external event being collisions with other players, which affected 12 % of the injured girls and 20 % of the injured boys. These findings led me to think about the reasons why young people were injured.

I had some questions. Why were there such different patterns in the circumstances surrounding sports injury? What associated risk factors (personal and/or environmental) were involved? I also asked: what methods could be used to bring clarity and generate interest to prevent these injury problems in the numerous sports clubs in Sweden?

Thoughts like these led to the embryo of a study plan and later continued studies as PhD-student. My journey as PhD-student has been long, crooked, demanding and punctuated by joy but also of personal tragedies and sorrows. Over the course of my research period, a chronic illness has resulted in long-term sick leave, thus, the gap between publication years. I've been close to giving up many times during this journey, but thanks to continuous support from my supervisors, Ragnar Andersson, Staffan Janson and Toomas Timpka I have finally reached the target with the research in this thesis.

ABSTRACT

From a public health perspective, promoting physical activity in children and youth has many benefits. However, in parallel with benefits, there are injury risks. Research suggests that about every fifth unintentional injury in a typical community in the western part of the world is associated with leisure time physical exercise. The injury risk increases with level of play and is associated with age, with about 32 % of sports injuries affecting the group 15-24 years of age (Swedish National Board of Health and Welfare, (Socialstyrelsen) 2010; Finch, Mitchell & Boufous, 2011). By understanding the factors associated with sport related injuries, relevance of age and injury mechanisms, sport safety practices can be applied in organised sports clubs serving children, youth, and young adults, as well as other age groups. For the time being, incidence rates and severity measures of injuries occurring in leisure-time sports are difficult to evaluate due to confusion about data collection methodologies, including confusion around definitions, such as which injuries should be classified as overuse injuries and how to measure and record the circumstances associated with serious sport related injuries.

The primary aim of this thesis has been to identify and investigate associated risk factors related to sport injuries. A secondary aim was to explore whether data from ambulance journals or different kinds of survey data can be used to identify injury or other health problems associated with sport, particularly affecting young people.

The thesis is based on three different surveys and one injury register study, with the results of these studies briefly identified below.

In paper I, which addresses governance and implementation of sports safety practices, research methods using case studies were used to compare sport safety activities in 73 strategically chosen Swedish municipalities; 14 WHO Healthy Cities (HC), 14 WHO Safe Communities (SC) and 45 control communities. A total of 616 (84.8 %) municipal offices answered the nested question about sport safety activities in the web survey.

The results showed that offices in municipalities accredited by WHO HC or SC organisations were more likely to perform frequent inspections of sports facilities and HC-designated locations were more likely to involve the sports

clubs in the inspections. The parties conducting inspections varied. In more than half of the study locations, these inspections were conducted by municipal property management and environmental protection offices. Less than 25% of all inspections were conducted by planning offices or social welfare offices. The study found that health and safety promotion programs can have effects on sports safety practices in local communities, and thereby raise awareness of safety issues in organised club sports for children and youth.

The ambulance surveillance study (paper II) provides epidemiological support showing that the ambulance services' regular surveillance data can be used as a data source to supplement analyses of moderate and severe injuries. However, at a population level, our results indicate that ambulance data capture a different proportion of moderate and severe injuries, compared to other data sources, and tend to overestimate some injury categories and underestimate others, among them, sport injuries in particular. Paper V, which analysed the ambulance attendance reports for sport related injuries from this larger study, found that ambulance records provided additional, and useful, information on injury location, which was otherwise very difficult, if not impossible, to obtain. The 'register studies' also point to a larger issue, that of the difficulty of reporting on sport related injuries using the current default classification system.

The focus of the studies in Paper III 'Rock climbing injuries and safety practices', and Paper IV, describing one-year injury prevalence of football injuries to school-aged players, are in describing risk factors associated with sports-related injuries in two specific activities. Paper III found that overuse injuries accounted for 93 % of all injuries in the study population of rock climbers, with inflammatory tissue damage to finger and wrists as the most common injury types. The high percentage of those injuries implies that climbing hours and loads should be gradually and systematically increased in order to reduce the amount of overuse injuries.

Paper IV found that youth reporting football injuries had higher standardized BMI compared with youth not reporting injuries and, among the injured players, children not reporting full health were slightly overrepresented. Pre-participation disparities in terms of parents' education levels, through interaction with gender, BMI and self-reported general health are associated

with increased risk for injuries in community based football. Communities should accommodate to these facts in their safety planning.

The thesis also provides information on the some of the theories and models that inspired this work, including, but not limited to, the RE-AIM theory (Finch & Donaldson, 2010) for analysing and evaluating health promotion efforts, the Essential Public Health Functions model (WHO and Pan-American Health Organisation, 2014), which was used to demonstrate how sport injury research contributes to Public Health, and Timpka et al.'s Framework for Sports Safety Promotion (2006).

The topic of sport injury is growing in importance, as more knowledge is shared on the benefits of physical activity. The research published in this thesis, it is hoped, can help contribute to safer sport practices, and a reduction in injuries during leisure time.

SAMMANFATTNING

Det finns belägg från ett folkhälsoperspektiv att främja fysisk aktivitet bland unga, även om ingen enighet om hur intensivt denna fysiska aktivitet skall bedrivas. Men parallellt med nyttan, finns det risk för skador. Forskning tyder på att ungefär var femte oavsiktlig skada i ett typiskt samhälle i västvärlden har samband med idrott eller motion på fritiden. Skaderisken ökar med spelnivå och åldern, från slutet av tonåren, t.ex. 32 % av samtliga idrottsskador påverkar gruppen 15-24 år. Genom att förstå de vanligaste typerna av skador, ålderns relevans, samt skademekanismer, kan säkerhetsrutiner tillämpas på unga människors föreningsidrott. För närvarande är detta svårt på grund av förvirring om metoder för datainsamling, inklusive definitioner, t.ex. vad som skall räknas som överbelastningsskador och allvarliga skador.

Det primära syftet med detta arbete har varit att identifiera och utreda riskfaktorer som har samband med sport-skador. Ett sekundärt syfte har varit att undersöka om ambulansrapporter eller olika slags enkäter kan användas för att identifiera hälsoproblem i samband med idrott.

Avhandlingen bygger på tre olika enkätstudier och en registerstudie. Artikel 1 baseras på fallstudiemetodik som används för att jämföra säkerhetsaktiviteter inom sporten bland 73 strategiskt utvalda kommuner i Sverige: 14 WHO Healthy Cities (HC) och 14 WHO Safe Communities (SC) samt 45 kontrollkommuner. Totalt 616 (84,8%) kommunkontor besvarade den inkapslade frågan om säkerhetsaktiviteter inom sporten i en webbenkät.
Resultaten visar att kommuner ackrediterade av WHO HC eller SC var mer benägna att genomföra frekventa säkerhetsinspektioner av idrottsanläggningar. HC-ackrediterade kommuner inkluderade oftare idrottsklubbarna i inspektionerna än övriga kommuner. Mer än varannan fastighetsförvaltning eller miljökontor genomförde inspektioner av idrottsanläggningar jämfört med färre än en av fyra stadsbyggnadskontor eller socialförvaltningar. Slutsatsen är att allomfattande hälso- och säkerhet främjande program kan ha effekter på säkerhetsrutiner inom sporten i lokalsamhället, och därmed öka medvetenheten kring säkerhetsfrågor som rör unga människors idrottande.

Ambulansregisterstudien (artikel II) gav användbara epidemiologiska data. På befolkningsnivå visade emellertid resultaten att ambulansdata fångar en annan

fördelning som inkluderar allvarliga och medelsvåra skador och som därigenom överskattar vissa skadekategorier och underskattar andra, inte minst idrottsskadorna som oftast är av mindre allvarlig natur. Denna registerstudie har sedan specifikt bearbetats (artikel V) angående idrottsrelaterade skador där den kan komplettera övrig akutstatistik med väsentlig information.

Genom att använda anpassade frågeformulär för att samla in skadedata (artikel III om klätterskador och artikel IV om ungdomars fotbollsskador), var det möjligt att få en bred bild av interna och externa riskfaktorer som kan ha samband med idrottsskador. Hos bergsklättrare stod överbelastningsskadorna för 93 % av samtliga skador, där inflammatoriska vävnadsskador i fingrar och handleder dominerade. För att förebygga den dominerande typen av skador bör att antalet klättertimmar och belastningsgrad öka gradvis.

Ungdomar som rapporterade skador inom fotbollen hade högre ålders-standardiserat BMI jämfört med ungdomar som inte rapporterade skador. Ungdomar som inte rapporterade full hälsa var något överrepresenterade. Sociala förutsättningar i form av föräldrarnas utbildningsnivå interagerade med ungdomarnas kön och BMI, liksom självrapporterad hälsa hade samband med ökad risk för skador inom den kommunbaserade klubbfotbollen. Kommunerna bör ta hänsyn till detta i sin planering.

Enkäterna i både studie III och IV behöver ytterligare anpassas för att möjliggöra analys av psykosociala integritetskränkningar. Vidare bör sjukvården och idrottsorganisationerna bättre identifiera specifika skador och deras allvarlighetsgrad för att kunna få ett bättre differentierat kodsystem, inte minst vad gäller skador vid idrottsgymnasierna, samt skilja på skador som sker på fritid respektive inom organiserad idrott.

TABLE OF CONTENTS

Innehåll

PREFACE 2
ABSTRACT 4
SAMMANFATTNING 7
TABLE OF CONTENTS 9
LIST OF PAPERS 11
ABBREVIATIONS 13
INTRODUCTION 14
Challenges in researching sport related injuries 14
Sport as a vital component of Public Health 16
Children and youth as sports participants 18
The development of epidemiology and public health from an injury prevention perspective 20
The epidemiology of sport related injury 22
Challenges in classifying sport related injury 28
Models that have influenced the research in this thesis 33
AIMS AND OBJECTIVES 38
The specific objectives of these studies are: 38
MATERIALS AND METHODS 39
Definitions used in this thesis 39
Data collection 41
Study design and participants 45
STATISTICS AND ETHICS 47
Statistical methods and analytic approach 47
Ethics 50
Ethical problems related to sport safety practices and injury surveillance 50
RESULTS AND DISCUSSION 51
Paper I. Governance and implementation of sports safety practices 51
Paper II. Ambulance surveillance 52
Paper III. Rock-climbing injuries and safety practices 54
Paper IV. One-year injury prevalence in youth football 56
Paper V. Ambulance records as sources for reporting of sport-related unintentional injuries 58
GENERAL DISCUSSION 60
Limitation in current studies 63
CONCLUSIONS AND FUTURE STUDIES 65

What this thesis adds 65
Challenges regarding future research 66
Suggestions for future studies 67
ACKNOWLEDGEMENTS 68
REFERENCES 70
APPENDICES 81
Appendix A. Operationalization of study constructs 81
Appendix B. Research questions and corresponding variables 82

LIST OF PAPERS

The thesis is based on the following papers, which are referred to in the text by their Roman numerals:

Paper I
Backe S, Janson S, Timpka T. Governance and implementation of sports safety practices by municipal offices in Swedish communities. International Journal of Injury Control and Safety Promotion 2012: 19(2):163-169.

Paper II
Backe SN, Andersson R. Monitoring the "tip of the iceberg": Ambulance records as a source of injury surveillance. Scandinavian Journal of Public Health 2008: 36:250-257.

Paper III
Backe S, Ericson L, Janson S, Timpka T. Rock climbing injury rates and associated risk factors in a general climbing population. Scand J Med Sci Sports 2009: 19:850-856.

Paper IV
Dahlström Ö, Backe S, Ekberg J, Janson S, Timpka T. Is "Football for all" Safe for all? Cross-sectional study of disparities as determinants of 1-year injury prevalence in youth football programs. PLoS ONE 2012: 7(8):1-7.

Paper V
Backe S. Ambulance records as sources for reporting of sport-related unintentional injuries. (Manuscript 2014).

DESCRIPTION OF CONTRIBUTORS

Paper I	
Study design	Stefan Backe
Data collection	Stefan Backe
Data analysis	Stefan Backe, Staffan Janson, Toomas Timpka
Manuscript writing	Stefan Backe, Staffan Janson, Toomas Timpka
Journal correspondence	Stefan Backe
Paper II	
Study design	Stefan Backe, Ragnar Anderson
Data collection	Stefan Backe
Data analysis	Stefan Backe, Ragnar Anderson
Manuscript writing	Stefan Backe, Ragnar Anderson
Journal correspondence	Stefan Backe
Paper III	
Study design	Stefan Backe, Lars Ericson, Staffan Janson
Data collection	Stefan Backe, Lars Ericson
Data analysis	Stefan Backe, Staffan Janson, Toomas Timpka
Manuscript writing	Stefan Backe, Lars Ericson, Staffan Janson, Toomas Timpka
Journal correspondence	Stefan Backe
Paper IV	
Study design	Örjan Dahlström, Stefan Backe, Joakim Ekberg, Staffan Janson, Toomas Timpka
Data collection	Stefan Backe
Data analysis	Örjan Dahlström, Stefan Backe, Joakim Ekberg, Staffan Janson, Toomas Timpka
Manuscript writing	Örjan Dahlström, Stefan Backe, Joakim Ekberg, Staffan Janson, Toomas Timpka
Journal correspondence	Örjan Dahlström
Paper V	
Study design	Stefan Backe, Ragnar Andersson
Data collection	Stefan Backe
Data analysis	Stefan Backe
Manuscript writing	Stefan Backe
Journal correspondence	Stefan Backe

ABBREVIATIONS

The following abbreviations, listed in alphabetical order, are used in this thesis:

BMI	Body Mass Index
BSSTM	Behavioural and Social Sciences Theories and Models
CI	Confidence Interval
EPHF	Essential Public Health Functions
FIFA	Federation of International Football Associations
GO	Governmental Organization
HC	Healthy Cities Network
ICD-10	The International Statistical Classification of Diseases and Related Health Problems, 10th Revision
IDB	Injury Database
IOC	The International Olympic Committee
NCECI	Nordic Medico-Statistical Committee Classification of External Causes of Injuries
NGO	Non-Governmental Organization
OR	Odds Ratio
P-value	A measure of probability that a difference between groups during an experiment happened by chance
RCT	Randomized controlled trials
RE-AIM	The RE-AIM Sports Setting Matrix including the dimensions: Reach, Effectiveness, Adoption, Implementation and Maintenance
SC	Safe Communities
SPSS	Statistical Package for the Social Sciences, a computer program for analysing statistics, used in all papers
SKF	Svenska Klätterförbundet [The Swedish Climbing Federation]
STATA	Data Analysis and Statistical Software, specifically used for zero-inflated Poisson's regression analyses in paper III
UIAA	International Mountaineering and Climbing Federation
WHO	World Health Organization

INTRODUCTION

This thesis describes a body of research that is aimed at reducing sport-related injuries, particularly those involving young people. These injury prevention efforts can be supported through core public health functions: policy, epidemiological analyses, and cooperation between regional and local authorities. This research was conducted from 2002, when ambulance response reports were analysed, through 2014, when a follow up study on the use of these reports to improve surveillance of sport-related injuries was completed. The research that is described in the thesis has its inspiration in a number of theoretical approaches, both to public health as a practice at national and community levels, and injury prevention, as it is implemented through policy directions, safety inspections of sport environments, and cooperation with sport organisations to identify risk factors associated with specific sport activities.

Readers will note a shift in the selection of words describing younger sport participants, at whom much of this research is aimed. At times, the thesis describes youth, at times, adolescents, and, occasionally, the term 'young people' is used. The variation is in large part due to differences in definitions in the studies are being discussed in the different parts of this thesis. The working definitions of studies that are cited here do not always coincide with each other, in part due to the way different sport organisations collected data, and in part due to differences in reporting systems. 'Youth', in this thesis, generally means children and adolescents who are enrolled in full time studies. 'Young people' can include adolescents and adults to the age of 25, while the term 'children' generally refers to sport participants in primary school. Note too that the study definition for sport used in this document is any activity that has rules, and involves physical exertion. Sports can be practiced in organised settings, or as informal activities.

Challenges in researching sport related injuries

From a public health point of view, there is a paucity of studies describing the outcomes of process evaluation for injury prevention programmes in sport environments, which makes it difficult to know why safety interventions are effective or not, particularly when these interventions are aimed at reducing sports injuries among younger players (Finch & Donaldson, 2010). Additionally, health services, municipalities and community sports clubs do not

have a clear picture of where sports injuries occur with regard to accurate injury-site addresses. These stakeholders also lack information on whether or not these injuries are associated with activities sponsored by organized sports clubs, nor do they know which community clubs are involved (Finch & Boufous, 2008; Finch, 2012).

There is also confusion about data collection methodologies, including definitions, such as how to define overuse injuries and serious sports injuries (Fuller et al., 2006; Schöffl et al., 2011). Likewise, theoretical gaps exist in research, for example regarding the extent of overuse injuries and the severity of these injuries in various sports, as well as the prevalence of psychosocial incidents such as threats and perceived bullying during organised sports.

From a preventive perspective, few studies have used any Behavioural and Social Sciences Theories and Models (BSSTM) as a precursor to fully understanding the behavioural determinants of safety actions (Finch & Donaldson, 2010; Finch, 2011; McGlashan & Finch, 2010). There is also an unclear demarcation of responsibility between public health authorities and sports clubs (Finch, 2011). In this context, studies have found that sport clubs were not aware if the municipality carried out safety inspections at stadiums that they were using

There are other challenges to the study of sport injury. The first is in defining what sport actually is. The debate extends as far as deciding which word to use in this research: is it sport-related injury, or sportS-related injury? The selection is largely based on whether one prefers to use UK-style English, or US-style English, it seems. The Oxford Dictionary defines sport as : 'An activity involving physical exertion and skill in which an individual or team competes against another or others for entertainment' (Oxford Dictionary, 2014). Sports, on the other hand, appears to be limited in UK style English as either an adjective modifying nouns, or as a noun describing a single event: 'An occasion on which people compete in various athletic activities' (Oxford Dictionary, 2014). This thesis follows UK-style language, as far as it is possible, and will refer to sport, rather than sports.

A second challenge to research sport-related injury is highlighted in the definition for sport that is provided above: sport can involve individuals or teams. A third difficulty is also illustrated in the definition, where Oxford points

out that sports can either be organised at a competitive level, or be practiced simply for the fun of it, as a leisure-time activity.

Perhaps one of the biggest challenges in research to prevent sport injury is that public health approaches to reduce injury risk for sport participants will be quite different, depending on whether public health actors wanted to reach individual participants who were doing sport activities alone, or with a few friends, as recreation, (what this thesis often refers to as *informal sport*) versus these public health actors wanting to reach a more organised group, with established practice times occurring at community-based sport facilities. Interventions based on researched risk factors will need to be adapted, depending on whether or not a sport is more often organised formally, or played informally.

In order to address these challenges, it is important to understand why sports are such an important component to Public Health.

Sport as a vital component of Public Health

The prevalence of non-communicable diseases has increased relative to communicable diseases in the western world. In this context physical inactivity and the resulting consequences of poor physiological fitness among children, adolescents, and adults, has become an issue of great public health importance to health professionals, governmental organizations (GOs) and non-governmental organizations (NGOs) (Krustrup et al., 2009; Micheli et al., 2011). According to World Health Organization (WHO), physical inactivity is ranked as the fourth leading risk factor for all deaths globally, contributing to 3.2 million deaths each year. Physical activity is a key component to maintaining a healthy lifestyle for all individuals (WHO, 2010).

The benefits of physical activity in health promotion and disease prevention for adults are widely established and extensively documented. For instance, physical activity has a key role to play in reducing the risk of premature death, coronary heart disease, type II diabetes, and colon cancer (Blair et al., 1996; O'Donovan et al., 2010). Furthermore, there is evidence of a dose-response relationship for such diseases. For other diseases, such as hypertension, high cholesterol, and osteoporosis, physical activity is also beneficial, although there is little data on the appropriate frequency (how often) and intensity (how hard) people must

participate in physical activity to obtain the best health effects (O'Donovan et al., 2010).

In response to the negative trend seen relating to increasing inactivity among children and youth, and based on current research showing strong evidence for the health benefits of physical activity undertaken by adults, WHO (2010) has issued a global recommendation on physical activity for health to children, adolescents and adults. WHO recommend that children and adolescents aged 5–17 years participate in at least one hour of moderate- to vigorous-intensity physical activity every day, supplemented by regular activities at least three times per week, for example, activities performed as part of playing sport, such as football (Dvorák, 2009), and including running or jumping that strengthen muscles and bones. This recommendation is consistent with the International Olympic Committee (IOC) expert group's consensus statement on the need to improve health and fitness of young people through physical activity and sport (Mountjoy et al., 2011).

However, the scientific evidence on which these guidelines are based appears to be rather weak. For instance, one study found that there is "hardly any evidence for a certain dose-response relationship or a particular threshold value from which guidelines can be obtained" (Twisk, 2001). This finding is echoed by Boreham and Riddoch (2001), who found no consensus in epidemiological data on the associations (e.g. no association, weak to moderate association) between physical activity by youth and physical parameters of current health status, such as blood pressure, bone health and aerobic fitness. The authors conclude that the reasons for these results due in part, to lack of large-scale longitudinal studies, combined with difficulties in measuring health, fitness and physical activity in children, and they state that more accurate measurement is needed (ibid).

However, other studies (Ekblom & Åstrand, 2000; Kelly, 1998; O'Connor et al., 1995; Baquet et al., 2004; Ford et al., 2011; Ganley et al., 2011) have found that physical activity, during sport and play is important for children's and adolescents' physical and neuromuscular development. In addition, despite the lack of clear evidence concerning training variables including maximal dose (e.g. volume, frequency, load, and rest periods) some research has found that strength training can be undertaken by children and adolescents, as long as the

programme is designed and supervised by professionals (Christou et al., 2006; Faigenbaum et al., 2009; Ford et al., 2011).

Children and youth as sports participants

A wide variety of sports are popular among children and youth. Football is by far the largest and most popular sport worldwide, and many of its participants are in younger ages. According to the Federation of International Football Associations (FIFA) in 2011, this sport is organised through 209 national associations and represents more than 265 million active players, most of them children and youth, around the world.

In Sweden, it is estimated that 69 % of children aged 7-14 years, and 39 per cent of all adolescents aged 15-19 years, participate in training and competing in a sports club. The five most popular sports among children aged 7-14 years are football (ca. 236,000 players), floorball (innebandy) (ca. 80,000 players), gymnastics (ca. 54,000 participants), martial arts (ca. 42,000 participants), and ice hockey (ca. 39,000 players). In the age-group 13-20 years, about there are about 156,000 football players, with floorball in second place with about 58,000 players, horseback riding in third place with about 44,000 participants, handball in four place with about 32,000 players and in fifth place martial arts with about 26,000 participants (Riksidrottsförbundet (Rf), 2011, s.3).

Within the age group 13-20 years, categorised by gender, the most popular sports are, for boys: football, floorball, ice hockey, martial arts and golf, and for girls: football, horseback riding, handball, floorball and gymnastics. Currently, in this age group, no dramatic differences of the position in sports popularity can be seen. Football is still the most popular sport in both genders (Rf 2011, s.3). However, the interest in sports such as climbing has increased in this age group between 2005 and the year 2011, for boys from 669 to 949 participants and for girls from 626 to 990 participants (Svenska Klätterförbundet [SKF] 2005).

Moreover recent surveys of time use by adults in Sweden found that in 2000 and 2010, women and men ages 20 through 64 reported an average of about half an hour a day that was used for sports and recreational activities taking place outdoors (Statistics Sweden 2014 A). A report that looked more closely at how time for sports and recreational activities was spent found that the most

popular activities for adults were hiking and talking walks, which implies a less formal type of activity. Respondents reported spending about 20 minutes per day on these activities, with other types of sports and recreational activities receiving far less time (Statistics Sweden 2014 B). In contrast, a national survey conducted in 2012-2013 showed that about 65% of respondents between the ages of 10 and 18 participated in organised sports at least one time a week (Statistics Sweden, 2014C). While the majority of the studies contained in this document are aimed at promoting injury prevention for sport participants of all ages, there is a special emphasis on prevention injuries to younger players, as shown in Papers III-IV, and V, thus the title of this thesis, *Safety promotion and injury surveillance with special focus on young people´s club sports.*

The development of epidemiology and public health from an injury prevention perspective

As the body of work described in this thesis is based from an injury prevention perspective, a brief description of the scientific base for this research is useful. This section provides a short historical overview of the development of epidemiology and public health science primarily from an injury prevention perspective, with a discussion on how this science impacts sport injury research.

Historically, the origins of "modern epidemiology and public health" can be traced to the industrial revolution and transformation of agriculture in 1700- and the 1800s in Europe, although some of central ideas of epidemiology and public health (e.g. to maintain health and prevent diseases and injuries) extend as far back as to the Hippocratic Oath (Beaglehole & Bonita, 1997; Dvořák, 2009). The 1800s were particularly important for the development of public health, as the industrial was associated with population growth, crowded and unsanitary urban environments, malnutrition and the transmission of air- and water-borne diseases amongst population (Beaglehole & Bonita, 1997; Susser & Susser, 1996).

The progress of epidemiology and public health science over time in Western industrialized countries has also seen changes in types of diseases and health problems affecting people the pre-and post-industrialization compared to present day. A progression in the changes of disease problems can be summarized with what Hjort (1994) describes as three different waves (infections → cardiovascular diseases, cancer, and injuries → chronic pain, allergies, mental illness). Chronologically how these public health problems actually succeeded each other is considered to be rather fluid- in many countries experiencing health transitions, multiple patterns take place at the same time (Beaglehole & Bonita, 1997; Susser & Susser, 1996).

The first wave of Public Health

During the "first waves" period of public health work (about early 19th century through first half of 20th century) the major causes of death were due to malnutrition, air- and water transmitted epidemic infectious diseases. The conquest of communicable diseases was based in large part on the development of statistical methods by epidemiologists for measuring outbreak of diseases. For instance, John Snow in 1854 mapped the cholera epidemic outbreak in the

district of Soho in England, and the work of William Farr and Jacques Bertillon to develop illness and injury classifications helped create the ICD-coding system, which is now used around the world as a tool to demonstrate clustering of morbidity and mortality. The ICD classification system is at present time updated in version ICD-10, and in Australia and New Zealand with modified (ICD-10-AM) activity sub-codes for identifying sport/leisure injury hospitalizations (Finch & Boufous, 2008).

Chronic disease epidemiology

An emerging welfare society with economic growth in the 1900s featured increased living standards among populations, which paralleled a changing disease panorama: the rise of non-communicable diseases around 1940s required other causal explanations and prevention strategies. Hereby the focus shifted from specific pathogenesis to risk factors – relating exposure to outcome. In the 1950s – 1960s epidemiologists developed methods for estimating relative and absolute risk, together with multivariate models that could be used to overcome the problems generated by limited data in the ordinary stratified analysis, for example, in studies on risk factor exposures to outcomes like coronary heart disease and injuries of different kinds (Beaglehole & Bonita, 1997).

Injury Epidemiology - development, approach and framework

In 1949, epidemiologist John E Gordon published his epoch-making paper entitled "The Epidemiology of Accidents", which conceptualized the interactions between the host, agent and environment. Gordon emphasized that injuries do not arise in a vacuum instead injuries occur according to *"the biologic principles that govern disease as a community problem are interpreted as holding equally for injuries"* (Gordon, 1949, p. 515). Based on Gordon's framework, Haddon (1964) theorized that *"all injury events are attributable to five forms of physical energy agents - mechanical, radiant, thermal, electrical, chemica*l", and in 1970s conceptualized "the ten countermeasure strategies to address injury control related to energy damage" (Haddon, 1970, 1973). Haddon was also responsible for another tool for analysing an injury event, a matrix that combines the features of the injury model and spectrum discussed above (Haddon, 1970). Both the "Haddon Matrix" and "the ten countermeasure strategies" have been used to illustrate etiologic factors for injury, for instance in road environment, playgrounds, and sports, and to identify potential preventive strategies (Runyan, 2003; Waller, 1994).

Although the debate continues among scientists regarding definition, causation and prevention issues related to accident and injury, it appears that the medical scientists in the field of Epidemiology and Public Health since the 1950s are by and large, using the biomedical "host-resistance" models as a framework in their efforts to measure patterns of disease/injury, combined with a narrow focus on individual health/prevention (Andersson, 2012; Gielen & Sleet, 2003; Meeuwisse & Love, 1997; Runyan, 2003; Timpka, Ekstrand & Svanström, 2006; Waller, 1994).

The epidemiology of sport related injury

What do modern epidemiological analyses tell us about sport related injury as a public health problem? Deaths from sport related injuries appear to be quite low, at least in Sweden. Analyses of injuries treated at the outpatient level, whether due to sport or other activities, are hard to capture in Sweden, and elsewhere. Most higher-income countries maintain hospital-based and Emergency Department-based injury registries, however, which make it a bit easier to compare hospital-based treatment for sport-related injuries. Sport-related injuries account for about one-fifth of all-age recorded injuries at emergency departments in the higher-income countries of Sweden, Australia and Norway (De Loës & Goldie, 1988; Finch, Valuri, & Ozanne-Smith, 1998; Lindqvist, Timpka, & Bjurulf, 1996; Ytterstad, 1996). In the 7–12 and 13–19-year age groups, the proportion of sports injuries in Sweden is even higher at 35% and 55%, respectively (Socialstyrelsen, 2010). Studies set in Sweden, and studies focusing on injuries for team ball sports (football, basketball, and handball) around the world have found that about 60-84% of sports-related injuries consisted of contusions (bruises and haematoma), fractures, sprains and strains (De Loës & Goldie, 1988; Emery et al., 2006; Finch, Valuri, & Ozanne-Smith, 1998; Richmond, Kang & Emery, 2013; Lindqvist, Timpka, & Bjurulf, 1996; Ytterstad, 1996). For males, fractures led ahead of contusions as the most common type of injury, whereas for females, the leading injury type was contusions. Gender differences were also noted with injuries to knee ligaments, with young female players displaying four to six times higher knee ligament injury rates compared to young male players participating in the same sports (Emery, Meeuwisse and McAllister, 2006; Emery and Tyreman, 2009; Soderman et al., 2001; Wedderkopp et al., 1997).

In team ball sports (football, basketball, and handball) lower extremities were injured in 50-55% (in descending order ankle/foot, knee and lower leg), upper extremities in 30-35% (finger and wrist as most common), and head in 10% of all cases. Moreover, football-related injuries constituted 35-45% of all sports injuries, with the most common injury location in lower limbs, about 55-60% of the cases (De Loës & Goldie, 1988; Finch, Valuri, & Ozanne-Smith, 1998; Lindqvist, Timpka, & Bjurulf, 1996; Ytterstad, 1996).

Risk factors for sport related injury in younger participants

Many of the available studies on sport related injury address football injuries, due to the international popularity of the sport (FIFA, 2013). To date, considering the overall literature from football and other ball sports, only a few studies have examined multi-factorial causality of football injuries. One such study looks at injuries to female youth footballers (Steffen, Pensgaard & Bahr, 2009) and in another study, Kucera et al., (2005) addresses injuries to female and male youth footballers. Moreover, Soligard's (2011) conclude that in most studies about risk factors associated with female youth football are typically evaluated separately, as in most cases where multiple potential risk factors have been recorded (e.g. age, gender, low muscle strength, previous injuries, skill level, etc.) they are often analysed in an univariate manner.

Risk factors for injuries in ball sports can be roughly divided into two categories, modifiable and non-modifiable factors. Potentially modifiable risk factors in ball sports include anthropometrics (weight, BMI), increasing or decreased hours of sport participation, joint instability, muscle strength, neuromuscular control, understanding of rules of play, pre-season training, injury rehabilitation, skill level and warm-up practices (Bahr & Krosshaug, 2005; Emery, Meeuwisse, McAllister, 2006; Emery & Tyreman, 2009; Hägglund, 2007; Soderman et al., 2001; Wedderkopp et al., 1997). Some psychological factors such as life event stress, anxiety and mistrust seem to be potential risk factors for injury, as well (Johnson & Ivarsson, 2011). Non-modifiable risk factors in ball sports include age, gender, height, previous injury, time of the season and weather conditions (Bahr & Krosshaug, 2005; Emery, Meeuwisse, McAllister, 2006; Emery & Tyreman, 2009; Hägglund, 2007; Soderman et al., 2001; Wedderkopp et al., 1997). The categorization into modifiable and non-modifiable risk factors can be applied to other sports. For example, regarding youthful rock climbers some of the potential modifiable risk

factors and non-modifiable risk factors are more or less the same as in ball sports (e.g. BMI, climbing disciplines and exposure hours, climbing grade level) as well as age, gender, height, previous injury, time of the season and weather conditions (Schöffl et al., 2012; Schöffl, Hoffman, Küpper, 2013).

How are sport-related injuries reported?

In order to learn more about risk factors associated with sport, particularly sport practiced by children and young people, it is important to have access to injury records. Maintenance of health records, including records of births and deaths, is considered to a primary function of public health at the national level (WHO, 2003). Many public health authorities maintain national registers that identify injury-related causes of death, and hospital based care for injuries. These registers, and other data bases with records related to treatment of injuries, collectively form injury surveillance systems, and can help identify the risk factors associated with individual sport activities. Surveillance is defined by WHO as "the ongoing and systematic collection, analysis, interpretation and dissemination of health information" (Holder et al., 2001).

In 1949, Gordon examined which components a surveillance system should contain, stressed that in order to achieve a better understanding of accidents and thereby improved measures of prevention, "the causes are sought through direct investigation of the site of the accident, of the associated circumstances, and of the person who was injured" (Gordon, 1949, p. 514). Subsequently, for implementation in the public health field, WHO defined surveillance as: "Surveillance refers to the on-going and systematic collection, analysis, interpretation and dissemination of health information" (Holder et al., 2001).

In the context of sports, van Mechelen used the term "surveillance" to describe the application of a 'four-step sequence of prevention'. In this model, *first*, the problem needs to be identified and described in terms of incidence and severity; *second*, the factors and mechanism which play a part in the occurrence of sports injuries have to be identified; *third*, introduction of measures that are likely to reduce the future risk of sustaining a sports injury and/or reduce the severity of sports injuries; *fourth*, the effect of the measures must be evaluated. Regarding step 3, van Mechelen states that "such measures should be based on the aetiological factors and the mechanism as identified in the second step (van Mechelen, 1997, pp. 164-165).

According to multiple researchers, a sports injury surveillance system's usefulness and success depends on valid and reliable definitions of sports injury, injury severity, and on the stakeholder/sports participants taking an active part (Bahr & Krosshaug, 2005; Finch, 1997; Fuller et al., 2006; van Mechelen, 1997; Schöffl et al., 2011; Siesmaa et al., 2011). Meaningful surveillance programs – those that contain accurate, comprehensive data – not are an easy task to develop, and require investments of time, money and personnel to implement and maintain. Some researchers have recognized the difficulties of conducting comparisons from studies on sports injuries and illnesses within and between different sports. Consensus statements on injury definitions and data collection procedures for studies on football injuries (Fuller et al., 2006) and for mountaineering and climbing sports (Schöffl et al., 2011) have been proposed. The content of these two consensus statements will be highlighted in the next section and also compared with the classification standards used in the health care.

There are compelling reasons for conducting injury surveillance in sports: such surveillance could capture young people's injury patterns in sport (Finch & Hennessy, 2000) and, in parallel with data on participation in training and competition, allow calculation of the real risk of injury (Finch & Cassell, 2006; Finch, 2012; Fuller et al., 2006; Schöffl et al., 2011; van Mechelen, 1997). Given that many youth participate in sport, (for example, in Sweden about 390 000 football players are in the age-group 7-20 years) the use of information from injury surveillance systems helps to highlight the need for prevention in this area.

What surveillance systems are used in Sweden to identify risk factors associated with sport related injuries?

There are three main components to Sweden's health and injury surveillance system: the Cause of Death Register (DOR), the hospital-based Swedish Patient Register, also called the Hospital Discharge Register (abbreviated in this study by its Swedish acronym (PAR), and Sweden's Injury Data Base (IDB).

The Cause of Death register registers all deaths of people who were officially registered as having resided in Sweden at the time of death, whether or not the death occurred in Sweden. Stillbirths are not registered, nor are deaths that occur to people on visit to Sweden. Deaths to people whose requests for asylum are being processes are also not records in DOR. The current register dates from 1961, and is updated each year. Cause of death is coded according to guidelines from the international version of 'The International Statistical

Classification of Diseases and Related Health Problems' (ICD), rather than the Swedish version. A more complete description of ICD is contained elsewhere in this section. The quality of reporting to DOR is generally considered to be of very high quality, with missing cases or information affecting between 1% and 2% of all deaths (Swedish National Board of Health and Welfare, 2014a).

The Swedish National Inpatient Register (PAR) contains records from all hospitals in Sweden. Cases reported to PAR include: all hospital stays of 24 hours or more, information on hospitalisations in geriatric and psychiatric hospitals and wards, information on patients who were treated by physicians in clinics outside primary care, and diagnoses and treatment of patients who were legally remanded to psychiatric treatment. The general quality of PAR is also considered to be quite good. Less than one per cent of all records go missing each year. Some reports, again, less than one per cent, but this issue primarily affects the records of children born outside Sweden. PAR reporting is coded using ICD-10 guidelines, and information on the main diagnosis for patients is missing in about 1 per cent of cases, however, reporting on hospital location, clinic location, sex and age of patient, and date of discharge are complete. Specific information on the external cause of injury is missing in 3% of cases related to injury-related hospitalisations (Swedish National Board of Health and Welfare, 2014b). The *external causes* of injury are defined by ICD 10 as the environmental events and circumstances that lead to the injury. These external codes include categories such 'exposure to forces of nature', for example, or 'Slipping, tripping, stumbling and falls' (Swedish National Board of Health and Welfare, 1997).

Another national register maintained in by Sweden's National Board of Health and Welfare as part of the injury surveillance system is the Injury Data Base Sweden (Swedish National Board of Health and Welfare, 2014c). Sport injuries are reported here using the NOMESCO Classification of External Causes of Injuries (NCECI). The data reported on sport injuries in IDB is limited. The database itself is limited to reports from participating hospitals, which currently cover only about 9% of the total population, but about 15% of the population needs to be in the catchment areas reporting to IDB, in order for the data to be completely reliable. The injury reporting also can lead to confusion.

Data recorded in IDB is structured so that different categories of damage and injury events may overlap. For example, the code W02 (cases in connection

with the use of skis, skates, skateboard or snowboard) are combined together. The different variables in IDB Sweden are not mutually exclusive. This means that it is not possible to determine serious injuries or deaths as a result of skateboards from deaths related to snowboard use. Another complication is that it is not obligatory to register specific sport codes, leading to lot of misses in the surveillance system. Similar problems are seen in other systems reporting to IDB Europe, with a selection of 100 hospitals in 27 countries that report around 300 000 cases a year (Eurosafe, 2013).

Voluntary collection of sport related injury data

Some sports associations in Sweden collect data on injuries reported by members during sports activities. For example, about 40-50 reports including both injuries and incidents (defined as a distinct event that could have resulted in a climbing injury, but was avoided at the last moment or escaped by a close margin), are delivered each year to the Swedish Climbing Association. Of these events fifteen deaths were reported during a 10-years period (all to adults). However, the total number of delivered reports as well as deaths associated with the sport may suffer underreporting as no mandatory reporting is required (Schöffl et al., 2010; SKF, 2011).

As comparisons, internationally the rates of serious injury during 2001-2003, were for rock climbing 6.6/100.000 (with no deaths) participants compared to the overall rates of serious injury (25 sports) of 1.8/100.000 participants for the state of Victoria, Australia. In the latter community, sports-related deaths were reported for motor-, aero-sports and water-skiing (Gabbe et al., 2005).

Other sources for injury data connected with youth sport

Additional injury reports are occasionally obtained from high-level competitions for youth, both inside Sweden, and internationally. For example, reports of injuries were conducted during World Championships in football 2008 (U-17 W Champ) with an average injury incidence ranging from 1.7 – 2.9 injuries per match (Dvořák, 2009). Body parts most likely to be injured were, in descending order for females: head (22%), ankle (17%), lower leg (17%), knee (15%), upper extremity (10%), trunk (7%) and thigh (7%), and for males: ankle (18%), lower leg (17%), thigh (14%), head/neck (14%), knee (12%), trunk (8%) and upper extremity (7%) (ibid.).

Some researchers have used research trials (cohort design) with the aim to implement routine injury surveillance (including exposure measurement) over an athletic season for community-level football. One such study in New Zealand followed 880 sports participants; seventy-eight per cent of players were male, and of the total, 539 (61%) were juniors under the age of 17. Telephone interviews with players were conducted each week to collect data on participation in matches and training sessions, injuries, and adherence to injury prevention measures (McNoe & Chalmers, 2010). A total of 316 match injury events and 75 training injury events were reported for juniors, with an overall incidence rate of 44.3 per 1000 player hours for matches, compared to 6.9 injury events per 1000 player hours, during training sessions. The most common injuries were sprains/strains (41.4% boys, 40.0% girls), and the lower limb was the most commonly injured body region in matches (68.4% boys, 76.6% girls) and in training sessions (79.7% boys, 68.8% girls). Tackling was the most common cause of injury. This study provided a much-needed first look at exposure versus injury outcomes for young football players.

Challenges in classifying sport related injury

Definition of an injury and an overuse injury

In order to make full use of injury surveillance systems, researchers must understand these injuries are classified. Historically, in the context of sports, there have been discrepancies in defining what actually constitutes a sports injury, and/or in reporting severity (Hägglund, 2007; Schöffl et al., 2011; van Mechelen, 1997). As an example, compare difference in reporting in two sports that are discussed in some detail in this document- football and mountain climbing. From a football perspective, three types of definitions of sports injury have previously been used in injury surveillance: time loss, tissue damage and medical attention. The first one, time loss definition seems to be most widely used both in elite football (adolescents/adults), and in youth football (Hägglund, 2007; Soligard, 2011).

A recently adapted consensus statement concerning studies of football (soccer) injuries defines injuries as:

"*Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time-loss from football activities. An injury that results in a player receiving medical attention is referred to as a 'medical-attention' injury and an injury that results in a player being unable to take a full part in future football training or match play as a 'time-loss' injury" (Fuller et al. 2006, p. 84).*

For climbers, the UIAA (The International Mountaineering and Climbing Federation) has defined an injury (trauma) as:
"*Any physical complaint due to an external or internal force sustained by a participant during trekking, mountaineering, or climbing activity." (Schöffl et al. 2011, p. 47).*
These two definitions differ a bit from each other. In the first case (football), the definition includes injury as physical pain, but also the level of medical attention and the health effects (time-loss) of injuries, with input open for the coach to decide. This brings about some complications. Firstly, time-loss can be referred to as an outcome - consequences of an injury. However the effect of a sports player's short or long time-loss also depends for instance on the time and quality of the rehabilitation programme (Hägglund, 2007). Secondly, coaches might choose to record either "medical attention" only or time-loss resulting in difficulties to compare different studies. Furthermore, time-loss reporting depends on the frequency of training and matches and this may introduce biases in amateur youth sports particularly (Bailey et al., 2010; Hägglund, 2007). The climbing injury definition seems narrower, but is in fact also extended to medical attention and time loss under its heading of severity classification, and normally is performed retrospectively.

There is a distinction to be made between traumatic and overuse injuries in sport participants. A traumatic injury is caused by physical damage that results when a human body is suddenly subjected to intolerable levels of energy (Holder et al., 2001). The trauma may result in a bodily lesion or fracture (to name just two traumatic injuries), or it can be an impairment of function resulting from a lack of one or more vital elements (i.e. air, water, warmth), as in drowning, strangulation or freezing. The time between exposure to the energy and the appearance of an acute injury is short.

The energy causing an acute injury may be:
• Mechanical (e.g. an impact with a stationary or moving object, person or animal such as vehicle in motion, blow, kick etc.);
• Radiant (e.g. a blinding light or a shock wave from an explosion);
• Thermal (e.g. air or water that is too hot or too cold);
• Electrical; or,
• Chemical (e.g. a poison or an intoxicating or mind-altering substance such as alcohol or a drug).

(Gibson 1961; Haddon, Suchman & Klein 1964; Holder et al., 2001; NOMESCO, 1997).

Overuse injuries differ from traumatic injuries. This injury type is defined both in the context of sports and in the context of medicine as: a condition with a gradual or sudden onset, resulting from repeated micro-trauma without a single identifiable event responsible (Fuller et al., 2006; 2007; Holder et al., 2001; NOMESCO, 1997; Schöffl et al., 2011). However, in the context of medicine, "Overuse injury" counts only as overuse injury within 48 hour. If the onset of the overuse injury was more than 48 hours ago, the injury is classified as a disease. This limitation results in bias, especially with regards to sports where the risk for overuse injuries can be high, such as bouldering and sport climbing (Morrison & Schöffl, 2007; Pieber et al., 2012). In the paediatric population, overuse injuries can include growth-related disorders (Osgood-Schlatter disease, Sever disease, and other epiphyseal injuries) and those resulting from repeated micro-trauma (Dalton, 1992; Shanmugam & Maffulli, 2008).

Classifications: sport injuries by severity

Understanding severity of sport related injuries is also important for intervention work. Injury severity can be classified according to the type of sports injury (the medical diagnosis), of the level of treatment provided and its duration (e.g. coach, paramedic, doctor in health clinic, emergency department and hospitalization), sporting time lost, working time lost, whether or not the injury left permanent damage, and-or associated costs (van Mechelen, 1997). The severity of injury often reflects the impact the injury has on the athlete's physiology and normally is measured by Abbreviated Injury Scale (AIS) or, in the case of head or brain injuries, with the Glasgow-Coma scale. The AIS describe the severity on a scale of 1 to 6, with 1 being minor, 5 severe and 6 an un-survivable injury, but the scale is not equal for changes between each level (e.g. severity step AIS2 to AIS3 is weaker vs. AIS4 to AIS5), thereby the scale is not very specific for minor grade injuries, which are more common in community-level youth football or in climbing sport (Schöffl et al., 2011).

The severity of injury in the context of sports often is based on the athlete's ability to participate fully in training and/or competitions (van Mechelen, Hlobil, Kemper, 1992; van Mechelen, 1997). According to consensus statements on injury definitions and data collection procedures in studies of football (soccer) injuries (Fuller et al., 2006; 2007), severity levels for these

sports injuries are defined as: slight (0 day); minimal (1-3 days); mild (4-7 days); moderate (8-28 days); severe (>28 days) and career-ending injuries. The severity classification published as a consensus statement on injury classification for mountaineering and climbing sports proposed differs in contrast to the definition used in football. Firstly, it comprises treatment level and outcome (e.g. work absence, permanent damage or death), secondly, it is a retrospective scoring systems (Schöffl et al., 2011). The International Mountaineering and Climbing Federation MedCom Scores offer another scale: 0 (No injury or illness); 1 (Mild injury or illness, no medical intervention necessary, self-therapy, i.e. bruises, contusions, strains); 2-3 (Moderate/major injury or illness, not life-threatening and requiring either conservative/minor or major surgery, outpatient therapy or hospitalization, doctor attendance within days or immediately, work absence, heals without or with permanent damage, i.e. un-displaced fractures, tendon ruptures, pulley ruptures, dislocations, meniscal tear, minor frostbite/or dislocated joint, fractures, vertebral fractures, cerebral injuries, frostbite with amputations); 4-6 (Acute mortal danger to immediate death). The scores 0-3 might be possible to compare with severity score (time-loss) in football.

Classifying sport injuries by mechanism and risk factors for injury

Understanding the relationship between external events, underlying injury mechanisms, and location of injuries can provide detailed information, which in turn can lead to targeted injury prevention work. This understanding is especially needed in sport research, as the number of activities for various sports differs widely.

The term 'injury mechanism' described how an injury was inflicted, i.e. how the person was hurt. If there is more than one mechanism, it is common to record the one that first precipitated the injury (Holder et al., 2001; NOMESCO, 1997). Injury mechanism reporting in the context of sports is usually only described in terms of whether the injury is due to player contact or not (Bahr & Krosshaug, 2005), which does not shed much light on injury circumstances.

Causes of injury (Hägglund, 2007) are generally categorized in sport research as intrinsic (person-related) risk factors or extrinsic (environmental-related) risk factors. Examples of each designation are given below:

Intrinsic (person-related) factors: Joint instability; muscle strength; tightness; body composition; psychological; and injury history.

Extrinsic (environment-related) factors: Level of play and position played; type of sport; exposure within the sport (match and training); sport equipment; warm-up/stretching; rules of play; floor and turf type/weather conditions.

These classification categories are fairly simple, but are usually found in combinations, which does not always allow for clear understanding of injury mechanisms.

Models that have influenced the research in this thesis

While the research in this thesis is presented using traditional epidemiological constructs, the research was also inspired by some models. A model can be defined as a 'simplified description of a system or a process' (Oxford Dictionary, 2014). Four models in particular are associated with the research in this thesis, which are described briefly below.

The role of public health authorities to address injury prevention efforts are described in the Essential Public Health Functions model, which could be used to implement interventions described in all papers. The RE-AIM Intervention model, specifically adapted to sport activity, also inspired context in which to recommend interventions, based on study findings for Papers III and IV, and is also briefly described in this section. A model for sport safety program design (SSPD) proposed by Timpka et al. (2006) helped form the thinking around intervention measures that could be promote empowerment and quicker adoption of safety practices in local sports organisations, and which help identify some of the intervention measures proposed later in this document. Finally, the programme models for two community based programmes are described briefly here, as they form an important research component of Paper I.

Essential Public Health Functions

The role of governments in protecting public health is fundamental one. The Pan-American Health Organisation, (PAHO), has described many of the rights granted to governments to protect public health, in its conceptual model, Essential Public Health Functions (EPHF). This model has been described in multiple policy documents published by WHO (see, for example, World Health Organisation, 2003; World Health Organisation and Pan-American Health Organisation, 2014). The model states that there are nine required functions that must be met by, or delegated via national governments. These functions are

- Health monitoring and analyses
- Epidemiological surveillance of disease, and prevention and control
- Development of policy planning in Public Health
- Strategic management of health systems and services for population health gain
- Regulation and enforcement of Public Health

- Human resources development and planning in Public Health
- Health promotion, social participation, and empowerment
- Ensuring the quality of health care personnel and population based health services
- Research, development, and implementation of Public Health practices.

  (Source: World Health Organisation and Pan-American Health Organisation, 2014.)

This model is included in this document, as proposed interventions described in all research papers would require the implementation of essential public health functions including, but not limited to, Epidemiological surveillance of disease, and prevention and control and Research, development, and implementation of Public Health practices. The model, and the research published here, points out the important role of policy makers to ensure sport safety.

RE-AIM sport specific matrix to evaluate sport related injury prevention

The RE-AIM model is a health promotion model designed to help public health practitioners translate research findings into real-life interventions. The model contains five steps, described below:

- Reach – the ability of the intervention to reach the intended target population
- Efficacy of the intervention in reducing sport-related injury
- Adoption of the intervention by target staff, settings, or institutions
- Implementation – evaluations should consider consistency, costs and adaptations made during delivery
- Maintenance of intervention , by evaluating the injury prevention effects in individuals and settings over time

The model is a relatively new one, but has already been cited in PubMed in more than 150 peer-reviewed studies. An adaptation of the model for sport settings has been described by Finch and Donaldson (2010), which accounts for the different levels in which sport is organised. The RE-AIM Sport Setting Matrix is depicted in Figure 1.

Figure 1. The RE-AIM Sports Setting Matrix (RE-AIM SSM): evaluation dimensions for community sport intervention delivery with demonstrable public health benefit (Finch & Donaldson, 2010)

	Level of assessment/intervention setting or target					
RE-AIM Dimension	**National Sporting Organisation (NSO)**	**State/Provincial Sporting Organisation (SSO)**	**Regional Association Or League**	**Club**	**Team**	**Participant**
Reach						
Effectiveness						
Adoption						
Implementation						
Maintenance						

Note: This table shows all possible intervention points. The relevance of each point will depend on the nature and target of each intervention

The RE-AIM Sport Setting Matrix is included here, because it provides a framework for implementation of safety interventions at the community setting, which is discussed in Papers III and IV. The Matrix can also be used to form evaluation processes.

The model for sport safety program design

This model is a relatively new one, and has not been tested. However, as the model illustrates the need for cooperation between public health actors and the sports community, including organisers and players, it has helped form thinking around interventions, which are described in the research published in this document. The model combines elements of Haddon's matrix, and assessment of socio-demographic factors to describe appropriate levels of intervention, as well as addressing injury reduction, and support for rehabilitation, if injury occurs. The emphasis is on learning from injury events, and intervening quickly, so that they do not reoccur. As the model is currently under modification, permission to publish it is suspended until these changes are made.

Models for community based programmes: Safe Communities and Healthy Cities

Two important community-oriented safety models have been associated with international networks via WHO, including the International Safe Communities Network, and the Healthy Cities network. Policy-wise both the Safe Community Movement (Welander, Svanström & Ekman, 2004) and Healthy Cities have their roots in the WHOs "Health for All" strategy and the Ottawa Charter, though they both are also inspired by participatory community development models and general health-promotion concepts – as addressed in life-style intervention trials for control of cardiovascular diseases in 1972-1977 in North Karelia (Farquhar, 1978; Puska, Tuomiletho & Salonen, 1981; WHO, 2009). The Healthy Cities network is primarily aimed at improving public health in general, while the Safe Communities network addresses injury prevention at the local level.

A Safe Community is defined as a local community, often a municipality, but other constellations can exist (e.g. groups with common interests, professional associations, or the individuals who provide services in a specific location). The underlying approach in on-going Safe Community programmes are to address all kinds of safety, and prevent injuries in all areas, all ages, environments and situations – involving non-governmental as well as governmental community sectors (Welander, Svanström & Ekman, 2004, pp. 49, 111). Since its formal adoption at the First World Conference on Accident and Injury Prevention held in Stockholm, Sweden in September 1989, the model has led to the development of several hundred community based safety promotion programmes with 34 in Scandinavia. Some of the Safe Communities programmes have also been reported as successful in reducing injuries from in sports and burns in children (Welander, Svanström & Ekman, 2004), but success has not been all inclusive (Nilsen, 2006). For example Timpka et al. (2005) reported social differences in injury reductions related to applied sports safety promotion program.

Many of these Safe Communities target childhood injury specifically as a part of their program activities, with sports safety a focus in many locations. In Sweden, six (e.g. Falun, Ludvika) of the fourteen Safe Communities-designated municipalities use a certification model for ensuring sports safety based on the Safe Sports model presented at the Safe Community conference in Nacka in year 2000. The model stipulates for instance that local sports clubs shall: perform safety inspections (at least once per year) in connection with a playing ground (e.g. Systematic fire protection work, control of operating equipment),

train volunteers in first aid and CPR, and have policies for doping/drugs, travel within the association, and report. The certification model for Safe Sports has further developed additional certification as Excellent Association/Compound, in cooperation between the municipality and the Educational Association of the Swedish Sporting Organisations (SISU). The municipality contributes money and SISU is the contact for ensuring the quality of prevention work, meaning that they are given the primary responsibility for co-ordinating interventions (e.g. gives suggestions on methods/tools, or provides process management).

Healthy Cities Sweden is part of the global WHO project Healthy Cities which engages local governments in health development through a process of political commitment, institutional change, capacity-building, partnership-based planning and innovative projects. In Sweden, at present time, 16 cities are members. As goal, member cities develop action plans on the basis of the national goals brought down to the local level. The local public health profile is based on measures of health and ill health, environmental factors related to health, non-healthy lifestyle and health-promoting behaviour and assessment of public needs (Healthy Cities Sweden, 2014). While Safe Communities focuses on community development to reduce injuries, the Health Cities has a broader program model, which calls for multifactorial efforts to promote health, for example, through smoking cessation, increased exercise, and better nutritional habits. The contrast between the two models creates a good opportunity to compare injury-related outcomes, as the models do not overlap much.

AIMS AND OBJECTIVES

The primary aim of this thesis has been to identify and investigate associated risk factors related to sport injuries. A secondary aim was to explore whether data from ambulance journals or different kinds of survey data can be used to identify injury or other health problems associated with sport, particularly affecting young people.

The specific objectives of these studies are:

To explore whether community-based all-purpose health programmes or safety promotion programmes and sports safety policies affect sports safety practices in club sports (Paper I);

To provide an epidemiological description of injury morbidity in a defined population on the basis of ambulance records in a Swedish county over 12 months, with special focuses on when, where and how these injuries occurred (Paper II) and to provide a description of sport-related injuries, both through organised sports events and spontaneous or informal play, which required ambulance attendance in Värmland County, Sweden. (Paper V);

To identify the frequency and associated risk factors that can be associated with injuries in climbing, and to identify rock climbers' formal climbing and first aid training and their safety-related practices (Paper III);

To explore if parents' educational level, player body BMI, and self-reported health are associated risk factors for an injury in community-based (club sports) football programs, separately or in interaction with age or gender (Paper IV).

MATERIALS AND METHODS

Definitions used in this thesis

Definitions: Children, Adolescents, and Youth

In sport contexts (according to the Swedish Sports Confederation), the term children is defined for players ages 0-12 years and adolescents are defined as players aged 13-20 years. Youth usually refers to the full period of childhood and adolescence (0-20 years). For the purposes of this thesis where children and adolescents are referred to collectively, the term youth (within age limit 7-18 years) will be used. In some studies, (see Paper V), the age group identified as young people includes sport participants through the age of 24.

Definitions of physical activity, exercise and training

Physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure, e.g. physical activities of daily living, active travel or transport, leisure time activity or occupation-related physical activity (Caspersen *et al.*, 1985; WHO, 2010).

Exercise and training may be described as a subset of physical activity which includes planned, structured, and repetitive bodily movements which are undertaken to improve or maintain one or several components of physical fitness (aerobic fitness, body composition, muscular strength, muscular endurance, power, speed, coordination, and agility) (Caspersen *et al.*, 1985; Stratton *et* al., 2004).

This thesis will focus on the term exercise and training in the discussions of sport safety practices and injury surveillance. Exercise and training with this definition are commonly used categories according to the definitions used in ICD-10, subdivided as one of nine main categories activity code categories, which describes the individual's principal activity at the time of the injury (Swedish National Board of Health and Welfare, 1997).

The concept of a dangerous event

These studies define danger as did Gibson (1961), where danger is an external source of potential energy or a thing that causes, or is likely to cause harm (personal injury, and/or material damage). Table 1 provides an overview of the definitions used in the four papers in this thesis.

Table 1. Summary of the definitions used in this thesis

	Used in paper	Definitions
Climbing incident	III	A distinct event that occurred while participating in a climbing activity indoors or outdoors and that could have resulted in an injury, but was avoided at the last moment or escaped by a close margin.
Dangerous events	III, IV	An external source of potential energy or a thing that causes, or likely to cause harm (personal injury, abuse event and/or material damage) [Slightly modified from Gibson, 1961].
Ambulance-attended injuries	IV, V	All contacts (patients' first visit) with ambulance services for treatment due to an injury (classifying as accidents/unintentional injury, violence or assault according to NCECI and ICD-10, Chapter XX).
Climbing injury	III	Injuries that occurred while participating in a climbing activity indoors or outdoors and that resulted in an injury treatment intervention (medical treatment, hospitalization and/or discontinuation and rest from climbing.
Football injury	II	An event (synonymously denoted dangerous event) occurring during a football match or training session that caused the player to miss at least one scheduled match or team training session or required medical attention.
Overuse injury	III, IV	A condition, with a gradual or sudden onset, resulting from repeated micro-trauma without a single identifiable event responsible.
Traumatic injury	II-III, IV, V	A condition caused by one identifiable event (acute onset).
Training exposure	III-IV	Team-based/individual physical activities related to training in football or climbing including warm up and cool down.
Competition exposure	III-IV	Team-based/individual physical activities related to competition (between different clubs) in football or climbing including warm up and cool down.

Data collection

Framework used to collect data for the thesis

The model used in this thesis is based on the epidemiological model of Meeuwisse (1994) and Bahr & Krosshaug (2005) combined with the socio-environmental framework as described by Timpka, Ekstrand and Svanström (2006, p. 738). The model includes a multi-factorial approach that visualizes the modifying and mediating mechanisms and risk factors in the inciting event phase involved in the occurrence of sports injuries or an abuse event that might lead to a psychological trauma. The mediating mechanisms, in contrast to the modifying conditions, are factors which normally are potentially modifiable by an intervention. The sections below describe the data collection used for each paper.

In Paper I Governance and implementation of sports safety practices, the questionnaire for surveillance was developed to provide information about sports safety practices in local communities, i.e. in existence of safety rounds and if sports clubs are involved in order to detect defects in the sports equipment and in the physical environment.

In papers II and V Ambulance surveillance data were used in order to identify where injury occurs in the community and mechanisms behind these injuries, and to assess the utility of these records to improve surveillance of sport related injuries.

In paper III Rock-climbing injuries and safety practices, the questionnaire for surveillance was developed to provide information around underlying individual risk factors associated to be predisposing for injury, i.e. body composition, gender, age and climbing experience. The survey also asked for information about amount of time spent on climbing per year, safety practices and self-reported accounts of climbing incident or climbing injury.

In paper IV One-year injury prevalence in youth football, the questionnaire for surveillance was developed to provide information about youth football player's safety and perceived security in connection with training and matches. Some of these aspects are illustrated in the study and other topics will be presented in a

future article. Items explored whether football players used protective equipment, encouraged drinking fluids regularly, warming up, cooling down at training and competition, and awareness of injury prevention strategies. These questions have previously been tested for its inter-rater reliability, test-retest reliability and content and face validity (Donaldson et al., 2003).

Background information on data collection and the development of different questions in the instruments is provided here.

In Paper I Governance and implementation of sports safety practices, the data collections were performed in two steps:

- A descriptive examination of sports safety policies identified from protocols and master plan documents in the municipality archives (n=73) and the Internet;
- The sports safety practice analysis based on statistical analysis of information from a web-survey (distributed during spring year 2005). Of the 1,251 potential responders representing offices with responsibilities for different municipal functions and sectors, 726 offices agreed to provide data.

In this study the responses to one of the survey questions 'Does your [municipality] office participate in surveillance of hazards at sports and leisure facilities?' were used for statistical analysis. Details regarding the data collection procedures and other questions used for the survey have been reported elsewhere (Johansson, Strömgren, & Backe, 2006; Strömgren & Andersson, 2010. If the office accepted such a responsibility, it was asked to answer the follow up question: 'How often does your office perform risk inventory/safety rounds at sports and leisure facilities?' The choices were: more than once a year, once a year, every two years, and less frequently than every two years. Respondents were also asked to give examples in free text of risks and hazards that were inspected regularly at the sports and leisure facilities. Thereafter, the office was asked whether it involved sports clubs in the safety inspections (yes or no).

In papers II and V Ambulance surveillance and injury reporting papers, the main data source in these studies were the regular ambulance registers. In Sweden, this register provides data about the medical status of an injured person and some information on the circumstances surrounding the incident

that caused the injury. These data are routinely collected on an ambulance record form as part of the ambulance services' on-site patient care responsibilities. It includes: ambulance/personnel identification numbers, time of the alarm call and priority; the patient's ID number, name, sex and place of residence; time, type and place/area of injury occurrence, including the patient's activity at the time of the injury; and preliminary diagnosis. Some of this information ('injury mechanism', e.g. struck, hit by contact with object, person or animal) was given in free text (narrative field) by the ambulance personnel. No instrument development was necessary. However, the data in these records that did not conform to ICD 10 categories were recoded, using NCEIC codes.

In paper III Rock-climbing injuries and safety practices, the data collections regarding the 2005 climbing seasons were collected during May – June 2006. The questionnaire contained four sections with preselected responses (tick the box format). The face validity of the survey questions was assessed by two physiotherapists (one with experience in climbing and one specialist on sport injuries) and a panel of local rock climbers (novice and experienced climbers) and the questions were revised according to the comments received. The first section in the questionnaire included questions about age, height and weight, climbing history/experience, climbing routines (use of protective equipment, warming up, etc.), first aid knowledge and retrospective accounts of dangerous event leading to a climbing injury (traumatic or overuse) or a climbing incident. Respondents were asked to specify how many climbing sessions (practice and competition) the climber had participated in each month and in total during the past 12 months, and how many hours active climbing (not including time for transportation or checking the equipment) was spent per session. Respondents who replied that they had been exposed to dangerous event leading to a climbing injury or a climbing incident were asked for circumstantial information about causes and outcome of them in the last part of the questionnaire. Information collected comprises type of injury, body part involved, treatment received, use of protective equipment and time and type of climbing activity.

In paper IV One-year injury prevalence in youth football, the data were collected 1 month after the end of the study-season 2006. All youth players belonging to the clubs at the start of the study season and their parents (for players under 15 years of age) received information in writing about the study and were asked to give their written consent to participation. Minors older than 15 years of age were only required to sign the form by themselves. The age of

consent was determined by the upper age limit for paediatric care in Sweden. The consent could be withdrawn at any time during the study without specifying the reason. A postal survey asking for data regarding the past season was sent to those consenting to participation. The questionnaire contained four sections with predominantly closed items (tick the box format). The first section in the questionnaire included questions about the number and duration of training/match sessions (total amount of time spent per day in a regular week in May and in September), transportation to the sport club, whether football players used protective equipment, encouraged drinking fluids regularly, warming up, cooling down at training and competition. The second and third section in the questionnaire exploring youth's self-reported health (illness/injury), physical capacity and awareness of injury prevention. The adolescent football players were also asked to assess their attitude to risk-taking during competitions on a five-graded scale. Finally, the fourth section in the questionnaire included questions about age, height and weight, and socio-demographic data.

Study design and participants

In paper I, case study research methods (Yin, 1994) were used to compare sports safety activities among offices in 73 of the 290 municipalities in Sweden: 14 with ongoing WHO Healthy Cities health promotion programme and 14 with ongoing Safe Communities programmes and 45 controls (with master plans from year 2000-2002). The municipalities were located in urban, suburban and rural areas in all geographic areas of Sweden and the population in the municipalities ranged from 3,700 to 482,000 inhabitants.

The specific focus attached to the objective for paper I is presented below and suggest being included under pre-event phase, 'mediating mechanisms'/external risk factors (e.g. sports facilities, floor or turf surface condition). The specific focuses in this study were to explore and describe the existence of explicit sports safety policies in a set of Swedish municipalities with and without all-purpose health or safety promotion programmes. Further, based on this description inform investigation of whether local all-purpose programmes or explicit sports safety policies are associated with community initiatives to reduce safety hazards at local sports facilities and with layperson participation in these initiatives.

In paper II, subjects were identified in the ambulance register maintained by the Värmland County, Sweden. Eligible cases were injured patients of all ages who were attended to, and registered by, ambulance services in Värmland County in 2002, and delivered to a hospital emergency department. Exclusion criteria including patients labelled as Duplicates, that is, an injured person first taken and treated by a general practitioner and further transported to the hospital. In these cases, the ambulance report from the first admission only was included for the analysis. In total, 0.9 % of the ambulance attendances were excluded on this basis. In Paper V, additional analyses of all sport related injuries were made, as a subset of the population described in Paper II. These were 323 of the total 3964 records, comprising about 8% of this larger group of records.

In paper III, a cross-sectional study design was used in order to collect self-reported data regarding climbing history, safety practices and retrospective accounts of dangerous event that could had led to or resulting to a climbing injury (traumatic or overuse). The invited study population consisted of 606 climbers, through a simple random sampling from all Swedish organized

climbers (n=6067, in 2005). A total of 37 surveys were returned unanswered due to an incorrect address, and nine respondents had left climbing. In total, 355 (63.4 %) of the remaining 560 surveys were returned answered. A dropout analysis directed to 102 of the 205 non-responders, answered by 64 individuals, didn't reveal any notable differences in terms of sex or age (<20 and 20+) between participants and non-participants.

In paper IV, a cross-sectional study design was used to investigate player-level data from one study season, based on the multi-factorial socio-environmental framework presented in text. The invited study population consisted of 1,230 youth players from four community football clubs, representing professional and amateur organizations (paid staff vs. volunteers). Sixty players (4.8%) chose not to participate in the study. In total, 767 youth players (62.4%) provided complete data sets. Following board decisions, all clubs agreed to take part in the study during the 2006 season (reaching between December 2005 and November 2006). Two clubs (Club A and Club B) were the largest clubs for youth football within their respective urban communities (municipalities with 50,000 – 200,000 inhabitants and more than 70 % urban areas). These two clubs also cooperated with elite clubs in the Swedish professional leagues. The two other clubs (Club C and Club D) were situated in suburbs of a large city (population 1,500,000). These clubs had no formal cooperation with professional clubs and their first teams played in regional amateur leagues.

STATISTICS AND ETHICS

Statistical methods and analytic approach

All statistical analyses were conducted in SPSS (SPSS for Windows version 15 or higher (IBM Inc., USA) or STATA (paper III) (STATA 10.2, Stata Corporation, Lakeway Drive, Texas, 2007). The significance level was set at 5 % ($p<0.05$). In all papers, to ensure accuracy, data were classified, checked and entered on two independent occasions by two researchers.

In paper I, two different statistical analyses were used: a combination of quantitative and qualitative text content analysis (Neuendorf, 2002; Weber, 1990) for checking if policy documents specifically state sport safety in action plans and involvement of sports clubs (e.g. players, coacher's) in the safety works; a combination of statistical methods (Chi-squared tests/multivariate regression analysis) were used for the study of associations between governance factors and community initiatives.

In the first part of the data analysis regarding *Sports safety policies*, documents were defined as sampling units and text paragraphs bounded with headline text as context units. The recorded units were the idea(s) or purpose(s) of the policy documents, e.g. master plans and WHO HC or SCs action programmes. The analysis began with searching each document for a number of predetermined keywords, e.g. sports injury, sports safety, safety policies, sports arenas, sports facilities, safety inspections, injury surveillance, and fire safety. The context unit for each located keyword was identified and demarcated, i.e. isolating the text where the keyword occurred in a paragraph (Key Word in Context search). The scanning and coding of the documents (covered 50-400 pages) took on average 1–2 h per document. Finally, the context units from the analysed documents were sorted into categories. Text excerpts from these categories were used to demonstrate typical formulations about sports safety promotion. The second part of the data analysis regarding *Sports safety practices* required additional coding: Municipality offices were grouped into four categories (Planning offices, Environmental protection offices, Property management offices and Social welfare offices) was performed. The offices were also coded with regard to existence of an all-purpose health or safety promotion programme in the municipality (WHO HC), SCs or no programme (control) and with regard to whether or not the municipality had an explicit sports safety policy, from which descriptive and analytic statistics were compiled.

The data were presented using descriptive statistics, frequency and relative frequency (%) for categorical variables. Differences in the proportions of subjects concerning involvement in sports safety inspections, and with or without an explicit sports safety policy/action document were analysed using the chi-squared test. In the second step, to explore the association between the dependent variables: frequent safety inspections (twice a year or yearly) and participation of sports clubs in the inspections (yes or no) and each of the independent variables, logistic regression analysis were applied with 95 % confidence intervals. Data from municipality offices not performing safety inspections were thus excluded from the analyses. The level of significance for the predictor to remain in the model was accepted at *P*-values < 0.05. Results from logistic regression analysis are presented as crude OR and adjusted OR with 95 % CI.

In papers II and V, Nordic Medico-Statistical Committee Classification of External Causes of Injuries (NCECI, 1997) was used, based on free-text information given by ambulance personnel in order to obtain more detailed descriptions about the circumstances of the injury events'. Details about the place of injury event occurrence, mechanism of injury and injury time were noted by 93-100% of the ambulance-attended cases. Data concerning injured body part, gender and age were noted in most cases. With reference to injured patients attended by the ambulance services were presented using descriptive statistics to calculate injury incidences together, when appropriate, with rate ratios, and frequency and relative frequency (%). In the second step, ecological comparison of selected parameters: external causes of injury (ICD-10 codes) and by age groups in 15-years intervals (owing to the confidentiality policy, Swedish National Board of Health and Welfare) between ambulance records and the hospital discharge register were done.

In paper III, the Orchard Sports Injury Classification System (Orchard, 1995) was used to classify the injury data by type and body location. Data were presented using descriptive statistics to calculate injury incidences, and frequency and relative frequency (%) for categorical variables. In the second stage, a two-step method including zero-inflated Poisson's regression analysis of re-injuries was used to determine the combination of risk factors that best explained individual injury rates. The following variables were included in the analyses: time exposed to climbing per year (continuous variable), body mass index (BMI) (continuous variable), sex (female/male), age group (<20/20–

45/>45), type of climbing practiced (traditional/sport/bouldering), and climbing experience (Novice: 0–4 year; Experienced: 5–9 year; Veteran: more than 9 years). Statistically significant variables were those with *P*-values < 0.05% or 95% confidence intervals that excluded unity.

In paper IV, the primary outcome measure in study was 1-year prevalence of football injury. A series of multivariate analyses (hierarchical) outgoing from the operationalization of study constructs (Appendix A) investigating with the primary outcome measure and interaction between the study variables (Appendix B). The test used to compare the observed with the expected frequencies was a log-linear analysis in this case (according to the role: no expected frequency should be less than 1 and not more than 20% of the expected frequencies should be less than 5). Each subgroup was examined with regard to the standardized residuals, that is, standardized measures for how much the specific subgroup differed from what would be expected. Cramer's V was used as a measure of effect size and for two-way interactions between dichotomous variables, the Rothman synergy index (Rothman, 2002) was reported to show the excess risk from exposure to both exposures when there is interaction relative to the risk from exposure without interaction (de Mutsert et al., 2009; 2011), that is, when there is no interaction, the synergy index is close to 1. The BMI of our sample was compared with reference values (Karlberg, Lou, & Albertsson-Wikland, 2001). The relation between BMI and injuries (Q3) was then investigated by comparing the gender- and age-defined z-scores of youths reporting injuries and those who did not, using independent samples t-tests. Descriptive data are presented as means with 95 % confidence intervals.

Ethics

The ethical issues related to the work of this thesis follow the WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects (WMA, 2004). *Papers II-V* were all approved by the Ethics Committee of Karlstad University, Sweden (# C2006/474, #C2005/ #UFO2003/2). *Paper I*, which relates to organizational issues, does not fall under the Helsinki regulations. All data used in this thesis are de-identified. The collected data in all four databases was managed and analysed without using the participant's personal identification number.

Each participant in studies I, III, and IV received written information regarding the objectives of the study and their participation involved. It was emphasized that participation was voluntary and that they could withdraw at any time. Consent was signed by participants and their parents (for participants under 15 years of age) in the study III-IV.

Ethical problems related to sport safety practices and injury surveillance

Medical professionals and researchers are bound by ethical principles in medical investigation (e.g. Hippocratic Oath, Declaration of Helsinki), and the principle of confidentiality is one very important feature of surveillance systems irrespective of if data are collected on individual or group level basis. Records of individual cases should be kept entirely confidential and surveillance reports must be presented in aggregated form so that individual cases not can be traced. Moreover, the system should never expose personal information (e.g. regarding signals of bullying, sexual abuse etc.) that can threaten people, and/or make the situation even worse. In the studies published here, all personal identifiers were removed before data analyses.

Many of the suggestions in this document are aimed at improving injury surveillance, but this surveillance is primarily targeting younger sport participants. Continuous surveillance of young people's club sports, may also lead to increased anxiety and/or a feeling of insecurity, and an unfortunate consequence that some youth choose to stop playing sports. Moreover, existing ethical principles and guidelines that govern clinical medicine and research studies may be hard to implicate to population based surveillance activity in youth sports with voluntary coachers. These ethical issues should be considered in every event.

RESULTS AND DISCUSSION

This section will describe the objectives of the research papers included in this thesis, along with each study's results, and a brief discussion of those results.

Paper I. Governance and implementation of sports safety practices

The objective of this study was to explore whether community-based all-purpose health programmes or safety promotion programmes and sports safety policies affect sports safety practices in club sports.

Results: Sport safety policies in the case study municipalities: Thirteen municipalities featured discussion of sports safety promotion in varied degrees in their policy documents (all-purpose health-, safety promotion programmes, and master plans). Seven (50%) of the 14 municipalities belonging to the WHO SC movement compared with two (14%) of the 14 municipalities included in the WHO HC programme and four (9%) of the 45 control municipalities had such policy documents specifically addressing sports safety. Regarding involvement of sports clubs in inspections, no control municipality or municipality belonging to the WHO HC programme mentioned sports club participation in their policies. Among the seven of the 14 municipalities belonging to the WHO SC movement that had explicit sports safety policies documented, two stated that sports clubs would be invited to participate in such inspections together with municipality offices. Three others had initiated more systematic injury prevention programmes through a safe sport club certification programme. Although detailed instructions, roles on procedures for inspections, and checklists identifying ten safety issues that the clubs must address were all mentioned, it was not clear who had the primary responsibility for carrying out safety inspections in these three groups.

Associations between municipality type, office category, and performance of sports safety interventions: One hundred and twenty-nine (58.7%) of the 220 offices that inspected sports facilities performed these inspections frequently. Eighty-one of them also involved sports clubs in safety inspections. The offices in municipalities with the WHO Healthy Cities (HC) or Safe Communities programmes were more likely ($p = 0.021$) to perform frequent inspections of sports facilities compared with control municipalities. Moreover, authorities were more likely to report that they involved sports clubs in safety inspections if the municipality was accredited by the WHO HC organisation (aOR 2.25; 1.04-4.89) or if the inspecting authority was associated with property

management (aOR 4.95; 2.35-10.42) or planning (aOR 3.48; 1.45-8.39) categories.

Discussions: The current study found that offices in municipalities belonging to the WHO HC or SCs programmes were more likely to perform frequent inspections of sports facilities compared with control municipalities. This suggests that all-purpose health and safety promotion programmes can reach out to have an effect on sports safety practices in local communities. However, contrary to the programme ambition, offices in municipalities belonging to the SC programme were not more likely to involve sports clubs in inspections. Also, organisational traditions affected the sports safety practices; property management offices were more likely to report that they involved sports clubs in safety inspections than the other authorities, and they were also more active in sports safety practices overall.

Paper II. Ambulance surveillance

This study was a base for the more specific study of sport injury, described in paper V. Papers II and V should be viewed in this context.

The objective of this study was to provide an epidemiological description of injury morbidity in a defined population on the basis of ambulance records obtained in a Swedish county over 12 months, with special focuses on when, where and how these injuries occurred.

Results: *Incidence of ambulance-attended injuries:* There were 3,964 ambulance attendances for injuries in the county of Värmland. This corresponds to a total ambulance attendance rate of 14.5 (95% CI, 14.0–14.9) per 1,000 population. In all age groups, with the exception of the elderly (75+) more male were treated by ambulance personnel for an injury than females.

Hour, month and day of the week: There was a weak seasonal variation with a slightly higher mean frequency during the summer months (June–August) than for the other months of the year. Most injuries (unintentional and intentional) occurred on Saturdays (711 out of 3,964 cases), but for intentional injuries (e.g. violence) most of these (83 out of 195) occurred from midnight to 6 a.m. ($eta^2=0.7$, $p<0.001$).

Place of occurrence and mechanism of injury: Most ambulance-attended injuries, (n= 1065, 25%) occurred in road traffic areas. Injuries in residential areas comprised the second most prevalent category with 784 injuries (20%), followed by school and institutional areas, with 548 injuries, (14%, mostly nursing homes) and sports areas with 323 injuries (8%). The most frequent cause of injury (mechanism of injury) captured in our data set was falling (63%, mostly in residential areas and in nursing homes), followed by contact with an object, person or animal (28%, mostly in connection with transport areas. In 58% of the injuries due to falling, the patients were female. Conversely, injuries resulting from contact with an object, person or animal were more prevalent in men (65%).

Discussions: This study attempted to monitor the overall occurrences of moderate and severe injuries, with special focuses on when, where and how these injuries occurred in a defined population by means of ambulance records. Our data suggest that 39.5% of the injuries resulting in ambulance attention occur among persons younger than 50 years of age. Regarding ambulance attended sports injuries most injured people are younger than 50 years (94%). Of the 323 registered sports injuries about 33% occurred in alpine environments, and about 18% in sports ground (e.g. football, athletics). In comparison, the Swedish Injury Data Base (IDB) reports that skiing injuries account for about 11% of sports related injuries and football for 28% (National Board of Health and Welfare, 2011). This difference may be explained by a geographical concentration of certain sports (dominant sport in each hospital catchment area). To our knowledge bandy, handball, skiing and hockey are the most popular sports, and if so, this could lead to underestimation of the number of injuries in these sports. However, overall sports injuries in children and adolescents are mostly limited to mild contusions, sprains and strains thereby ambulance records may be biased, underestimated other sports i.e. football, bouldering, sport climbing.

Other factors related to sports injuries, i.e. most popular sport, most frequent injury mechanism and injury location (anatomical sites) among/between girls and boys our findings is also replicated in other studies (De Loës & Goldie, 1988; Emery, Meeuwisse and McAllister, 2006; Emery and Tyreman, 2009; McNoe & Chalmers, 2010; Ytterstad, 1996). In this study population, the ambulance personnel can localise the place of injury event occurrence by using a digital map. The position can be determined by using Global Position System

(GPS) coordinates, and by so identify the street/place name and address. By using this device the ambulance personnel could report the place of injury event occurrence, mechanism of injury and injury time for 93-100% of the ambulance-attended cases. This precision of reporting is also shown in recent epidemiological studies where mechanism of injury was documented in 78% vs. 80-92% of all ambulance-attended cases (Boeke, House, & Graber, 2010; Staff & Søvik, 2011). GPS records and digital maps provide a strength in injury reporting, compared to hospital records and emergency room-based injury surveillance systems where this type of information is missing to a higher degree (Brenner et al. 2002; Lund et al. 2004; Tercero et al. 2006).

In conclusion, this study provides some epidemiological support for ambulance services might be a potential source of regular surveillance on moderate and severe injuries, both from sports and other causes. However, at a population level, our results indicate that ambulance data catch a different proportion of moderate and severe injuries and by so tend to overestimate some injury categories, and underestimate others, as compared to hospital data. However, the data also show that there are a reporting bias regarding some sports, particularly underreporting of sports like floorball, athletics, handball and basketball.

Paper III. Rock-climbing injuries and safety practices

The objective of this study was to identify the frequency and associated risk factors that can be associated with injuries in climbing. The study also aimed to identify rock climbers' formal climbing and first aid training and their safety-related practices.

Results: 208 injuries were reported, corresponding to 4.2 injuries per 1000 climbing hours, from a random sample of 606 members of a national rock climbing association. One hundred and six climbers (30%) reported at least one injury, with the proportion injured higher for male climbers (34.5%, 95% CI: 28.6%-40.4%) than for females (18.9%, 95% CI: 11.4%-26.3%). Overuse injuries accounted for 93% of all injuries, and 28% of the participants reported at least one such injury. Inflammatory tissue damages to fingers and wrists were the most common injury types. Fingers and wrists (42%) were also the most common anatomical location for overuse injuries, upper arm (26%) coming in second and shoulder (13%) coming in third. The quotient between upper limb injuries and lower limb injuries was the highest in traditional climbing, with a

ratio of 9:1 (n=36:4) in contrast to 5:1 (n=54:11) for sports climbing. Traumatic injuries constituted only 7% of all injuries and only 4% of the climbers reported having sustained traumatic injuries during the 2005 season. Of the traumatic injuries, 50% involved the lower extremities (foot, toe and ankle), while upper extremities accounted for 36%. Nearly all climbers (85%) who had sustained a traumatic injury had received medical attention, while 15% of the injured climbers required hospitalization, mostly due to a fracture.

The primary regression analysis showed an increased risk for sustaining a climbing injury for climbers with a higher BMI (β 0.046, P<0.015) and for those participating in the bouldering discipline (β 0.300, P<0.047). In the zero-inflated Poisson's regression analysis of risk factors for re-injury, significant differences in injury incidence were found between the sexes and age groups. Being male was associated with a higher re-injury risk (β 0.574, OR 1.77; 1.10-2.87, P<0.019) and a lower injury risk was observed for the two oldest age groups.

The main underlying factors reported by the climbers to explain the traumatic injuries and incident events were human factors (mistakes or lapses in concentration) (40%), followed by equipment failure (20%). The majority of these injuries and incidents occurred on rock ledges or rock faces (64%). Moreover, in all, 74.6% of the participants had taken part in a climbing course, 85% of which were held by an authorized instructor (no differences seen between the age groups). However, very few (13%) had participated in a first aid course or in a climbing rescue course.

Discussions: This study found that injuries occurred at an overall rate of 4.2 injuries per 1000 climbing hours (for traumatic injuries: 0.28 injuries per 1000 hours of climbing of all sub-disciplines), and that overuse injuries accounted for 93% of all injuries. These injuries predominantly involved the upper limbs, with the finger most affected. Our results regarding body parts injured are in line with other studies published (Gerdes et al., 2006; Neuhof et al., 2011; Paige et al., 1998; Pieber et al., 2012). However, the findings that overweight and practicing bouldering was associated with an increased injury risk, while there was a higher re-injury risk among male climbers and lower risk among the older climbers, contradicts to other studies. Neuhof et al. (2011) found that age, years of climbing experience and average climbing level were correlated to the injury severity rated through NACA scores, and Pieber et al. (2012) found that

climbers with older age and higher exposure to climbing stress seem to be more prone to injuries. A possible explanation for these differences is that the previous studies may not have captured representative samples from the general climbing population, preferring instead to recruit participants by convenient sample from climbing websites (Gerdes et al., 2006; Neuhof et al., 2011; Paige et al., 1998; Pieber et al., 2012). A consensus statement on injury definitions and data collection procedures was published after this study began (Schöffl et al. 2011). It stipulated that climbing grades should be reported with the single standardized metric scale. One hypothetical explanation for the different pattern could be that the climbing experience in our study does not reflect exactly the same climbing experience as in other studies, which have used climbing and mountaineering graded scales (Neuhof et al., 2011; Pieber et al., 2012). For instance, some of the experienced climbers in our study might have changed to climbing lower grade scales (reflecting an aging process, e.g. other values and by so lower the risk of being injured).

This study was used a cross sectional design, similar to most studies of the injuries and accidents and associated risk factors in climbing and mountaineering sports. Our data shows a high percentage of overuse injuries, which implies that climbing hours and loads should be gradually and systematically increased. Although there are accumulating scientific data supporting these findings, our data should be interpreted with caution for reasons that this study design does not allow one to determine specific causal relationships between risk factors and climbing injury. Further study of the association between different kinds of predisposed factors, i.e. body mass, biological growth, fitness level, skills etc. and climbing injury is warranted.

Paper IV. One-year injury prevalence in youth football

To explore if parents' educational level, player body BMI, and self-reported health are associated risk factors for an injury in community-based (club sports) football programs, separately or in interaction with age or gender

Results: Exposure to football and anthropometrics; There was no gender difference in the mean exposure to football practice and games, which ranged from about 4 hours per week among the youngest players to more than 7 hours among the players aged 15–18 years. About 1 in 3 children in the younger age groups had parents with low education, decreasing to 1 in 4 of the older children. In contrast, less than 1 in 10 of the youngest children reported low

self-reported health, compared with almost every third girl and every fifth boy in the oldest group. Girls had on average higher BMI than reference groups (t (9) = 4.77, P= .001, r = .85). Only at age 12 years did the BMI of the girls fall short of the reference values. Boys had on average 0.29 standard deviations higher BMI than reference groups (t (9) = 5.52, P<.001, r = .88). They had higher BMI than the reference groups at all ages.

Regarding One-Year Injury Prevalence and Interactions between Injuries, Gender and Age (Q1): The general 1-year injury prevalence (having sustained ≥1 injuries during the study season) was higher among boys than among girls for all age group. The lowest injury prevalence was recorded for the players aged 8–10 years. For both genders, the highest 1-year injury prevalence was observed in the 15–18 years age group girls (74% CI, 60-88); boys (77% CI, 68-86). Among the players aged 15–18 years, (27% CI, 17-37) of the boys and (21% CI, 8-34) of the girls sustained 4 or more injuries.

Regarding Interactions between Injuries and Parents' Educational Level (Q2): For youths with parents with higher formal education, boys reported injuries to a higher degree and girls reported injuries to a lower degree than expected (χ^2(1, N= 474) = 9.99, P = .002, Cramer's V = .15, Rothman's synergy index = 4.62). For youths with parents with lower educated parents there was a tendency towards the opposite pattern.

Regarding Interactions between Injuries and BMI (Q3) *and Interactions between Injuries and Self-reported Health* (Q4): Youths reporting injuries had higher standardized BMI compared with youths not reporting injuries. Children not totally healthy were slightly overrepresented among those reporting injuries. The first 2-way interaction (self-reported health and injuries; χ^2 (1, N= 688) = 8.80, P = .003, Cramer's V = .11, Rothman's synergy index = 0.24) displayed: Children not reporting full health were slightly overrepresented among those reporting injuries (standardized residual = 1.7) and under-represented for those reporting no injury (standardized residual = -2.2). The second 2-way interaction (self-reported health and age group; χ^2 (1, N= 764) = 14.97, P = .002, Cramer's V = .14) displayed: Children not reporting full health were underrepresented in the age-group 8-10 years (standardized residual = -2.5) and overrepresented in the age-group 15-18 years (standardized residual = 2.5).

Discussions: This study found that risk factors including parents' educational level, gender, BMI, and self-reported general health were associated with increased injury risk in community-based youth football. However, the slightly increased injury risk observed, is not a reason to discourage overweight children and adolescent participating in football programs. Instead, when football programs are introduced as part of general health promotion programs, modifiable risk factors, including poor postural control and physical fitness, should be identified and addressed to ensure that overweight children and adolescents can participate in football activities as safely as possible. Our results also point out that in community-based football programs there is a need to create awareness among coaches and club officials of common health issues among players.

Paper V. Ambulance records as sources for reporting of sport-related unintentional injuries

To provide a description of sport-related injuries, both through organised sports events and spontaneous or informal play, which involved ambulance attendance in Värmland County, Sweden. This study focused on describing how, when, and where which people were injured during sport activities, with an aim to describe how ambulance reports can augment information from other injury surveillance systems.

Results: Overview of all ambulance-attended injuries, by age and sex
During the study period, there were 3,964 ambulance attendances for injuries in Värmland County. This corresponds to a total rate of 14.5 (95% confidence interval (CI) 14.0–14.9) ambulance attendances per 1,000 population. Of these total attendances, 323 (8%) were due to sport injuries. People ages 0-24 comprised 52% of total sport injury cases attended by ambulance. Older adults, ages 25 plus, comprised 21% of total cases. Age information was missing in about 27% of cases. Sex was recorded for all but three cases (1%). Males composed 72% (n= 233) of all sport related injury cases in this study, with females comprising 27% (n= 87) of cases.

Injury type and mechanism of injury
Falls comprised leading cause of sport related injury requiring ambulance attendance (n=164, 70%), followed by contact with another person (n= 33, 14,1%). Lower limbs were most likely to be the body parts injured (n=103, 34%), followed by injuries to head or neck (n=78, 25%), and by upper limbs

(n=73, 24%). Analysis of injury mechanism categorised by age group shows that falls were significantly more likely to occur among younger people when analysing cases where age was known (Pearson Chi-square 11.726, $p < .008$).

Place of injury

The ambulance records all contained precise addresses, using GPS-based information, to pinpoint where injuries occurred. Due to ethical constraints, this study has categorised these settings into more general categories. Alpine settings (ski areas and other mountain sport settings) were associated with the largest number of sport related injuries requiring ambulance attendance, followed by sports centre (sports halls, gyms, or similar buildings), sports grounds and ice rinks. Injury locations where age of injured person was known show similar patterns

Due to unequal distribution of age groups and missing information on ages, analysis of injury type, mechanism and location by sex could not be done, as in some cases, five or few cases would be reported in a few categories. Quality of information is provided by free text fields. Although free text was available for records, about 15% of all ambulance attendance reports were missing information in this field.

Discussions: This study showed that male sex and younger age was associated with higher risk for sport related injury requiring ambulance attendance. These findings were not unexpected. One of the more surprising findings, however, was the large number of injuries occurring in alpine settings. As locations with high injury numbers are clearly identified in the study, interventions to reduce sport related injuries should probably target these areas first.

The study pointed out the utility of ambulance records to augment ICD-10 hospital based surveillance systems. The ambulance records provided detailed information on location and injury mechanism that are otherwise missing. One drawback to nationwide analysis of ambulance records in Sweden, however, is that the reporting forms vary between counties. Standardized reporting processes can increase the utility of ambulance records for use in regional comparisons. The usefulness of an expanded ambulance based reporting system for sport injuries and other injuries would benefit not only injury researchers, but also ambulance responders and other public health officials.

GENERAL DISCUSSION

The primary aim of this research has been to identify and investigate associated risk factors related to sport injuries. A secondary aim was to explore the use of injury surveillance data to identify injury problems associated with sport related injuries, particularly those injuries affecting young people.

What can be learned from the research in this document, as regards the aims stated here?

What new ideas can this thesis provide about risk factors associated with sport injuries and use of surveillance data from ambulance responses to sport injuries?

In paper III, which described rock climbing injuries and safety practices, and in paper IV, which discussed injury prevalence in youth football, these studies addressed a set of predisposing factors with possible association to injury risk, albeit with slightly different approaches. In paper III, contextual data from injury events was collected, but no data were collected about other risk factors. In paper IV, there was no ambition to record biomedical and contextual data from injury events; instead other data was collected about ill health. Paper V demonstrated that younger sport participants had higher risks for fall injuries, and that the majority of ambulance attendances for sport injury were for events occurring in alpine settings. The paper pointed out differences in risk for males and females, and provided additional evidence that sport participation decreases quickly, as adults reach their later 20s.

Data from paper III showed that being male, having a relatively high BMI and participating in bouldering were associated with an increased injury risk. These findings are supported by other epidemiological studies (McHugh, 2010; Schweizer, 2012). It has been suggested that modifiable risk factors, i.e. poor postural control (leading to problems with balance and coordination), and poor physical fitness (associated with muscle fatigue and subsequent injury) mediate this risk (McHugh, 2010). Results from the climbing study in Paper III also show that overuse injuries accounts for 93% of all injuries, with 28% of the participants reporting at least one such injury. Our findings are in accordance with other climbing studies (Jones et al., 2007), studies on sport events (Ekberg et al., 2011), injuries to other athletes (Jacobsson, 2012), and female youth football players (Soligard et al., 2010), however, at a much lower degree. This indicates that our results may be skewed due to erroneous reporting of

traumatic injury as overuse injury. Never the less, these combined findings demonstrate that overuse injuries in sports might be a greater public health problem than previously been observed by general practitioners or through analyses of hospital data.

Data from paper IV showed a positive association between age-adjusted player BMI and increased injury risk, that is, individuals with larger body mass relative to their player peers displayed an increased injury risk. These findings presented are supported by data collected from adolescents (12-19 years) from 59 high schools in Alberta, Canada (Richmond, Kang & Emery, 2013). Their results also showed that there was a greater risk for an injury with increasing hours of play per week, and among those adolescents who played at club level (OR=2.12, 95% CI: 1.57-2.87) compared to less competitive levels of play (Richmond, Kang & Emery, 2013).

In our football study (paper IV) we found 10-20% of the adolescent players reported less than optimal health and that low self-reported health was associated with increased injury risk. In our study population, asthma and allergies were the most common self-reported medical problems (unpublished data). In a recent Swedish study among high school male and female football players, Johnson & Ivarsson (2011) found that four significant predictors (life event stress, somatic anxiety, mistrust and ineffective coping) explain 23% of injury occurrence. Pre-disposing factors identified which might have a role were: pressure from schoolwork, parents and coaches as well as social relationships with peers. A hypothesis postulates that the greater risk of drop outs from sport (e.g. due to injury or competing) seen among low skilled player as well as high skilled player may depend on slow maturity in some young players (Jones, Hitchen & Stratton, 2000; Soligard et al., 2010).

The results from paper IV indicated that in community-based football programs, there is a need to create awareness among coaches and club officials of common health issues in players. These issues may interfere with the players' fitness or coordination and increase their injury risk. Information from a focused pre-participation medical history can be used to prevent the occurrence of an injury or illness. Moreover, the findings in paper III-IV have shown that population surveys can be useful for to generate data on physical and behavioural characteristics, i.e. BMI, sport-specific skills, illness and perception of risk, which normally are not measured as risk factors associated with injury

in adolescents. Such information might also contribute to a deeper knowledge of the socialisation occurring during sport.

What new ideas can this thesis provide about improving injury surveillance of sport injuries, particularly to young people?

Paper I, Governance and implementation of sports safety practices, paper II, Ambulance surveillance, and paper V, Ambulance records as sources for reporting of sport-related unintentional injuries, discuss other ways apart from traditional surveillance in sports to identify potential factors that may have an impact or influence on sport safety practices. Data from paper I displayed that all-purpose health and safety promotion programmes can reach out to have an effect on sports safety practices in local communities. The performance of safety inspections for the purpose to detect ill-maintained facilities in sports arenas, type of rescue equipment available, etc., might be a way to improve the cooperation between municipality offices responsible for sports safety and sports associations with their sports club. Our findings and conclusions are in line with other studies (Bjärås et al., 1990; Donaldson et al., 2004; Swan et al., 2009).

The findings from papers II and V support the secondary aim of this research, by demonstrating how some of the injury data captured by ambulance personnel possibly could be used to raise awareness of sports injuries occur in the municipality. In particular, ambulance records can provide detailed information about the place of injury occurrence and good information on the circumstances surrounding the incident that caused the injury. However, as ambulance services only capture a small proportion of the moderate and severe sport injuries this study indicates that ambulance data will probably be best used as a complement to other injury surveillance systems.

These findings are similar to a study done Staff & Søvik (2011) on the quality of ambulance documentation of injuries in Norway, in that both studies indicate a need for improved procedures, training, and tools for ambulance based injury documentation.

Paper V found that hospital based reporting in Sweden often lacked information on injury location, injury mechanism, and sport activities that contributed to injuries. The paper clearly identified the need to augment existing reports. Future improvements to sport injury reporting should consider categorisation systems that are specific to sport, for example, the Orchard system, which provides more detailed information for diagnosing sport injuries, which can also be useful in the treatment of these injuries (Orchard, 1995). It should be possible to augment sport injury reporting even further. Study IV shows that sports organisations can be very willing partners to develop and implement sport-specific injury reports

Limitation in current studies

In general, our knowledge about risk factors for acute- and overuse injuries comes from epidemiological studies, and thus conclusions are based on statistical association, not on experimental evidence. This means that we cannot with certainty say that the risk factors are causal. For practical and economic reasons, two studies in this thesis were conducted with a cross sectional design, which affects interpretations of the results. One cannot tell whether our findings in paper IV, "that the 1-year injury prevalence was higher among boys, and that the injury prevalence also increased with age", reflect biological factors, such as end-pubertal growth, nor can the study account for older players who left the community clubs aiming for a professional career or as a consequence of injury.

Other limitations that need to be taken into account when interpreting our results relate to information bias, i.e. misclassification bias in form of reporting bias/recall bias. In paper I, respondents who report that they conduct sports safety inspections were asked to describe in narrative which environments were included in these inspections. However, the sports facilities considered in questions about sports safety inspections were not named. The responses therefore did not reveal whether all sports venues in the municipality were inspected regularly. Furthermore, in all retrospective surveys, both underreporting due to memory decay and over-reporting due to telescoping may bias the analyses (Delgado-Rodriguez & Llorca, 2004; Harel et al., 1994; Mock et al., 1999; Petridou et al., 2004). Our data concerning self-reports for injuries and/or self-reports for BMI (paper III and IV) might be biased. Additionally, it must be acknowledged that computing of BMI from self-reported weight and height data is inferior to using data from standardized

measurements. However, other studies have demonstrated acceptable reliability in self-administered reports of BMI, self-reported climbing grades reflection of climbing ability, and in self-administered reports of injury details such as the body part injured (Bulik, 2001; Draper et al., 2011; Valuri et al., 2005; Villanueva, 2001). However, self-administered reports on injury severity have been found to not correspond sufficiently to medical records (Gabbe, Finch, Bennell et al., 2003; Siesmaa et al. 2011; Valuri et al., 2005;), and because of that, data on severity were not collected in our studies (paper III-IV).

The results from paper III may be skewed due to the probability that non-injured climbers were over-represented among the non-participants; it is likely that the injury incidences and proportions reported in the study over-estimate the actual injury risk. The results on traumatic pulley ruptures may have been misclassified as overuse injuries (it's unclear whether these overuse injuries had been verified by ultrasound and magnetic resonance imaging). In view of these issues, but balanced by positive feed-back/narrative text surrounding the circumstances from the respondents, we still believe that our self-reported injury recall data (paper III-IV) is fairly reliable for use in epidemiological analyses, but some in both questionnaires need to be further developed.

Results from these studies must also be weighed against the representativeness of the sample populations. In paper I, the study included only a subset (n=73) of the 290 municipalities in Sweden and may not be fully representative of all municipalities. However, the studied municipalities represent a mix of different social, demographic, economic and organizational characteristics so these municipalities might not differ greatly from the rest. The results of the ambulance register studies (papers II and V) may not with certainty be generalized to the rest of Sweden. The climbing study (paper III) is most possibly representative for Swedish climbers, due the simple random sampling methods used. In paper IV, our sample of youth players from clubs in urban and suburban areas was chosen to be representative for Sweden with regard to club policies and socio-demographic settings. There may be other specific sports environments (e.g., football academies and small clubs in rural areas) where the results do not apply. However, we consider the external validity to be satisfactory for most youth football settings in Sweden; the generalization to other contexts must be made with care.

CONCLUSIONS AND FUTURE STUDIES

What this thesis adds

Results from study I demonstrate that all-purpose health and safety promotion programmes can reach out to have an effect on sports safety practices in local communities. These safety practices also reflect administrative work routines and managerial traditions. Further, our result suggests that adequate guideline (e.g. how to carrying out safety inspections, who are responsible etc.) and adequate follow up's if policies e.g. safety inspections routines and cooperation with sports clubs as stipulated in safety promotion programmes follows is vital for the work to affect sports safety practice.

Our data in paper III show high percentage of climbing-related overuse injuries, in that, sex, BMI, climbing discipline, such as bouldering and sport-specific skills is associated to the increased injury risk.

Findings in paper III-IV point toward that the questionnaires in both study III and IV need to be further developed for possibilities to analyse psychosocial integrity violations (in paper IV) and additionally how Haddon's Matrix (pre-event-, inciting-event-, post-event phases) could fit into a novel multi-factorial approach that could visualize the modifying risk factors and injury mechanisms involved in these injury processes.

Results from studies II and V have helped met the secondary aim of this combined research project by demonstrating that reporting deficiencies exist, under the current ICD 10 system. The studies identify a pressing need to gather and analyse additional information related to injury occurrence, mechanism, and injured body parts. The studies point out a need for continued support for Essential Public Health Functions, via funding and additional reporting sources, for injury surveillance systems.

Challenges regarding future research

Caroline Finch (2012) argues that the major reason for the lack of cohesive sport injury policies by government authorities for health or sports to date is due to a lack of relevant information available for policy makers. Moreover, policy actions need to be integrated across government portfolios including sport, health and others. Until sports medicine research generates high quality population level information of direct relevance and importance for policy makers, sport injury prevention will be left off the public health agenda (Finch 2012).

In order to help policy makers and other stakeholders in sport communities to promote safer sport, more information on sport-specific risk factors must be routinely collected via surveillance systems. Methodological considerations around the surveillance models for sport-related injuries need to be addressed in future studies, including the feasibility implementing sports-specific surveillance systems, for instance, in community-level football. First, the surveillance system must be designed in a manner so that accurate reporting can be continuously provided. Due to the voluntary nature of administering and coaching in young players' sports clubs, some financial incentives are probably needed to support such reporting (Schiff et al., 2010). Second, reporting in to surveillance systems must be authorised by all who participate, i.e. coaches, youth players/athletes, and their parents. Third, ethical issues, including confidentiality and privacy for participants, must be ensured. The integrity of the data related to collection, dissemination and the use of such data to motivate club sports safety action should be protected, whether or not the data is collected via questionnaires, web programs or SMS text (Declich & Carter, 1994; Jacobsson et al., 2010).

Who should report on sport related injuries to children and young people? Several previous studies on youth sports injuries have described the use of medical staff (e.g. physicians, certified athletic trainers or physical therapists) to report on the number of injuries (Emery et al., 2005; Price et al., 2004; Soligard, 2011), and some have reported reporting follow-up rates in the range of 76% to >90% (Emery et al., 2005; Price et al., 2004). It's argued that accuracy can be improved by not using self-report methods with the intention of reporting sports injuries (Emery el al., 2005; Fuller et al., 2007; Soligard, 2011). Yet, other studies have noted good reliability and high weekly response rates ranging from 85% to 92%, illustrating that the use of nonmedical personnel (coaches,

athletes, parents) and media, i.e. SMS or web-based systems may be a feasible way of collecting exposure and injury data in these populations (Jacobsson et al., 2010; Moller et al., 2012; Shiff et al., 2010). It appears that the key to a meaningful study of the epidemiology of sport-related injury to children and youth lies in a well-organised procedure for data collection with coordinated efforts from sports medicine professionals, coaches and athletes, combined with systematic subsequent analyses. The use of medical professionals to report on injuries/time loss prospectively is relatively expensive and thereby might not be practical for young people's club sports. More research studies of different kinds are needed in order to develop feasible injury surveillance within sports clubs (McNoe et al, 2010; Schöffl et al. 2011).

Suggestions for future studies

- Due to non-conclusive findings in climbing studies on injury rates and associated risk factors within different climbing in a general climbing population, larger prospective studies on subgroups are warranted, to identify risk factors (e.g. BMI, maturity, sport-specific skills etc.).
- Evidence concerning preventive measures in climbing are weak and further studies in this field are needed.
- The development, analysis and interpretation of health- and sport-related injury of data in partnership between the health sector and the sport sector and participating communities should be investigated.
- Other studies could investigate if a theoretical framework such as Diffusion of Innovations and the RE-AIM Sports Setting Matrix (reach, effectiveness, adoption, implementation and maintenance) for program evaluation and for understanding the implementation context for community sport could interact with the Haddon Matrix.

ACKNOWLEDGEMENTS

I am very grateful to everyone who has helped me making this thesis possible. Especially I would like to express my sincere gratitude to the following people:

I am grateful to all respondents for their participating in the surveys. It is obvious that without you this thesis would not have existed.

My thanks go to Hans Karlsson, LIV (County Council of Värmland) for the extraction of injury data from the ambulance medical records database and Anders Karlsson from the Swedish National Board of Health and Social Welfare for providing data from the hospital discharge register.

There are lot of other people I would like to thank who have supported me and my work along what turned to be a long and winding road, punctuated by joy but also of real dark life crisis. Without continuous support and encouragement from all three supervisors, including supervisor Ragnar Andersson and supervisor Staffan Janson at Karlstad University, and my informal supervisor Toomas Timpka at the Department of Medical and Health Sciences, Linköping University, for valuable and constructive comments from draft to final paper, I would never have survived these years.

I also wish to thank Anna Johansson and Mattias Strömgren for the supportive and cooperative efforts to collect data for the paper 'Governance and implementation of sports safety practices by municipal offices in Swedish communities'.

A special thank you to Caroline Finch and colleagues at University of New South Wales, Sydney, Australia who have contributed with discussions, comments and advice concerning injury surveillance with special focus on young people´s club sports.

Thanks go to colleagues and friends at Public Health Sciences at Karlstad University for constructive advice and encouragement through the years, special to, Inge Svedung, Anna Johansson, Helena Rådbo, Malin Larsson, Birgitta Svensson, Mattias Strömgren, Johanna Gustavsson and Finn Nilsson.

Thanks also to Diana Stark Ekman for correcting the vocabulary and for improving my written English.

My PhD scholarship came from the (former) Swedish Rescue Services Agency and the Swedish Civil Contingencies Agency (MSB). In addition the studies have been supported by grants from the Swedish National Centre for Research in Sports (CIF), Karlstad University and Linköping University.

Some thoughts in Swedish

Till att börja med vill jag rikta ett tack till mina tre handledare.

Tack Ragnar Andersson för att du ha stöttat och delat med dig av din kunskap inom det skadepreventiva fältet, samt för att ha introducerat mig i doktorandstudierna och i den folkhälsovetenskapliga forskningsmiljön vid Karlstads universitet.

Tack Toomas Timkpa för din entusiasm, ödmjukhet och positiva framtoning under alla åren som gått. Dina värdefulla synpunkter och enastående kunskaper i fotbollsmedicin och idrottssäkerhet med särskild inritning på unga människors föreningsidrott har varit mycket uppskattat och verkligen imponerande.

Sist men inte minst vill jag tacka dig Staffan Janson för uppmuntran och starka tålamod. Det har verkligen varit givande och stimulerande att få lära känna dig såväl yrkesmässigt som privat. Jag vill också tacka dig för dina värdefulla diskussioner och allt stöd, i synnerhet under den svåra tiden det senaste året. Utan ditt engagemang hade jag definitivt inte rott i land med denna avhandling.

Ett tack även till mina medförfattare Örjan Dahlström och Joakim Ekberg för många givande diskussioner och kloka synpunkter. Det har varit inspirerande att arbeta ihop och förhoppningsvis uppkommer fler tillfällen framöver.

Jag vill också tacka min underbara familj, släkt och vänner som stöttat mig, inte minst under slutet av avhandlingsarbetet.

Avslutningsvis vill jag tillägna denna avhandling min Mamma som efter en tids sjukdom rycktes från livet alldeles för tidigt.

REFERENCES

Andersson, R. (2012). The role of accident theory in injury prevention – time for the pendulum to swing back. *International Journal of Injury Control and Safety Promotion*, 19 (3), 209-212.

Backe, S., Ericson, L., Janson, S. & Timpka, T. (2009). Rock climbing injury rates and associated risk factors in a general climbing population. *Scand J Med Sci Sports*, 19, 850-856.

Bahr, R. & Krosshaug, T. (2005). Understanding injury mechanisms: A key component of preventing injuries in sport. *Br J Sports Med*, 39, 324-329.

Bailey, S., Scase, E., Heynen, M. & Magarey, ME. (2010). A review of sports injury data collection literature and recommendations for future research. *The Internet Journal of Allied Health Sciences and Practice*, April: 8 (2), 1-13.

Baquet, G., et al. (2004). Effects of a short-term interval training program on physical fitness in pre-pubertal children. *J Strength Cond Res*, 18 (4), 708-713.

Beaglehole, R. & Bonita, R. (1997). *Public health at the crossroads: achievements and prospects*. Cambridge University Press, Cambridge, United Kingdom.

Bjärås, G., Danielsson, K., Schelp, L., Sjöberg, D. & Skjönberg, G. (1990). Safety rounds in public environments: Experience of a new tool for prevention of accidental injuries. *Accid Anal Prev*, Jun 22 (3), 223-228.

Blair, SN., Kampert, JB., Kohl, III. HW., Barlow, CE., Macera, CA., et al. (1996). Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *Journal of the American Medical Association*, 276, 205-210.

Boeke, PS., House, HR. & Graber, MA. (2010). Injury incidence and predictors on a multiday recreational bicycle tour: The register's annual great bike ride across Iowa, 2004 to 2008. *Wilderness Environ Med*, Sep, 21 (3), 202-207.

Boreham, C. & Riddoch, C. (2001). The physical activity, fitness and health of children. *Journal of Sports Sciences*, 19 (12), 915-929

Brenner, RA., Scheidt, PC., Rossi, MW., Cheng, TL., Overpeck, MD., et al. (2002). Injury Surveillance in the ED: Design, implementation, and analysis. *Am J Emerg Med*, 20, 181-187.

Bulik, CM., Wade, TD., Heath, AC., Martin, NG., Stunkard, AJ., et al (2001). Relating body mass index to figural stimuli: population-based normative data for Caucasians. *Int J Obes Relat Metab Disord*, 25 (10), 1517-1524.

Caspersen, CJ., Powell, KE. & Christenson, GM. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Rep*, 100, 126-131.

Christou, M., Smilios, I., Sotiropoulos, K., Volaklis, K., Pilianidis, T., & Tokmakidis, S. (2006). Effects of resistance training on the physical

capacities of adolescent soccer players. *Journal of Strength and Conditioning Research*, 20, 783–791.

Dalton, SE. (1992). Overuse injuries in adolescent athletes. *Sports Med*, 13 (1), 58-70.

Declich, S. & Carter, AO. (1994). Public health surveillance: Historical origins, methods and evaluation. *Bull WHO*, 72, 285-304.

Delgado-Rodriguez, M. & Llorca, J. (2004). Bias. *J Epidemiol Community Health*, 58, 635-641.

de Loés, M. & Goldie, J. (1988). Incidence rate of injuries during sport activity and physical exercise in a rural Swedish municipality: Incidence rates in 17 sports. *International Journal of Sports Medicine*, 9, 461-467.

de Mutsert, R., de Jager, DJ., Jager, KJ., Zoccali, C. & Dekker, FW. (2011). Interaction on an additive scale. *Nephron Clin Pract*, 119 (2), 154-157.

de Mutsert, R., Jager, KJ., Zoccali, C. & Dekker, FW. (2009). The effect of joint exposures: Examining the presence of interaction. *Kidney Int*, 75 (7), 677-681.

Donaldson, A. & Finch CF. Applying implementation science to sports injury prevention. *Br J Sports Med 2013*. Published Online: March 16, 2013. doi: 10.1136/bjsports-2013-092323

Donaldson, A., Forero, R., Finch, C. & Hill, T. (2004). A comparison of the sports safety policies and practices of community sports clubs during training and competition in northern Sydney, Australia. *British Journal of Sports Medicine*, 38, 60-63.

Donaldson, A., Hill, T., Finch, CF. & Forero, R. (2003). The development of a tool to audit the safety policies and practices of community sports clubs. *Journal of Science and Medicine in Sport*, 6 (2), 226-230.

Draper, N., Dickson, T., Blackwell, G., Fryer, S., Priestley, S., et al. (2011). Self-reported ability assessment in rock climbing. *Journal of Sports Sciences*, 29 (8), 851-858.

Dvorák, J. (2009). Give Hippocrates a jersey: Promoting health through football/sport. *Br J Sports Med*, 43 (5), 317-322.

Ekberg, J., Timpka, T., Ramel, H. & Valter, L. (2011). Injury rates and risk-factors associated with eventing: a total cohort study of injury events among adult Swedish eventing athletes. *International Journal of Injury Control and Safety Promotion,* (18), 261-267.

Ekblom, B. & Åstrand, PO. (2000). Role of physical activity on health in children and adolescents. *Acta Paediatr*, 89, 762-764.

Emery, CA., Meeuwisse, WH., Hartmann, S. (2005). Risk factors for injury in adolescent soccer: Implementation and validation of an injury surveillance system. *Am J Sports Med*, 33 (12), 1882-1891.

Emery, CA., Meeuwisse, WH., McAllister, JR. (2006) A survey of sport participation, sport injury and sport safety practices in adolescents. *Clin J Sport Med*, 16, 20-26.

Emery, CA., Tyreman, H. (2009) Sport participation, sport injury, risk factors and sport safety practices in Calgary and area junior high schools. *Paediatr Child Health*, 14 (7), 439-444.

Eurosafe, Injuries in the European Union, Report on injury statistics 2008-2010, Amsterdam, 2013. Available (2014-01-07) from EU Injury Data Base

http://ec.europa.eu/health/data_collection/docs/idb_report_2013_en.pdf

Eurosafe. (2013). *Home and leisure injuries: self-reported incidence.* Online report. http://www.eurosafe.eu.com/csi/eurosafe2006.nsf/wwwVwContent/C6005A1C3F6FA646C1257D040047971A?opendocument&context=91EC988C515ED595C125717E00323154.

Faigenbaum, A. D., Kraemer, W. J., Blimkie, C. J. R., Jeffreys, I., Micheli, L. J., Nitka, M. et al. (2009). Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *Journal of Strength and Conditioning Research*, 23 (5, suppl.), S60–S79.

Farquhar, J. (1978). The community-based model of life style intervention trials. *American Journal of Epidemiology*, 108, 103-111.

Federation of International Football Associations [FIFA website]. Available (2013-02-24) from http://www.fifa.com/worldfootball/bigcount/

Finch, CF. (1997). An overview of some definitional issues for sports injury surveillance. *Sports Med*, Sep: 24 (3), 157-163.

Finch, C., Valuri, G. & Ozanne-Smith, J. (1998). Sport and active recreation injuries in Australia: Evidence from emergency department presentations. *British Journal of Sports Medicine*, 32, 220-225.

Finch, CF. & Hennessy, M. (2000). The safety practices of sporting clubs/centres in the city of Hume. *J Sci Med Sport*, 3(1), 9-16.

Finc,C. Boufous,S. (2008). Do inadeequacies in ICD-10-AM activity coded data lead to underestimates of the population frequency of sports/leisure injuries? *Inj Prev* 14, 202-204.

Finch, CF. & Donaldson, A. (2010). A sports setting matrix for understanding the implementation context for community sport. *Br J Sports Med*, 44, 973-978.

Finch, CF., Gabbe, BJ., Lloyd, DG., Cook, J., Young, W., et al. (2011). Towards a national sports safety strategy: Addressing facilitators and barriers towards safety guideline uptake. *Injury Prevention*, 17(3), 1-10.

Finch, CF., Mitchell, R. Boufous, S. (2011). Trends in hospitalised sports/leisure injuries in New South Wales, Australia – implications for the

targeting of population – focused preventive sports medicine efforts. *J Science Med Sports*, 14, 15-21.

Finch, CF. (2011). No longer lost in translation: the art and science of sports injury prevention implementation research. *Br J Sports Med, 45, 1253-1257*.

Finch, CF. (2012). Getting sports injury prevention on to public health agenda - addressing the shortfalls in current information sources. *Br J Sports Med, 46, 70-74*.

Ford, P., De Ste Croix, M., Lloyd, R., Meyers, R., Moosavi, M., Oliver, J., Till, K. & Williams, C. (2011). The long-term athlete development model: Physiological evidence and application. *J Sports Sci*, 29 (4), 389-402.

Fuller, CW., Ekstrand, J., Junge, A., Andersen, TE., Bahr, R., Dvorak, J., Hägglund, M., McCrory, P., Meeuwisse, W.H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scand J Med Sci Sports*, 16, 83-92.

Fuller, CW., Molloy, MG., Bagate, C., Bahr, R., Brooks, JH., Donson, H., et al. (2007). Consensus statement on injury definitions and data collection procedures for studies on injuries in rugby union. *Clinical Journal of Sport Medicine*, 17 (3), 177-181.

Gabbe, B.J., Finch, C.F., Bennell, H., Wajswelner, H. (2003). How valid is a self-reported 12 month sports injury history? *Br J Sports Med*, 37, 545-547.

Ganley, et al. (2011). Health-related fitness in children and adolescents. *Pediatr Phys Ther*, 23, 208-220.

Gerdes, E.M., Hafner, J.W., Aldag, J.C. (2006). Injury patterns and safety practices of rock climbers. *J Trauma*, 61 (6), 1517-1525.

Gibson, JJ. (1961). The contribution of experimental psychology to the formulation of the problem of safety – a brief for basic research. In: *Approaches to Accident Research*. New York: Association for the Aid of Crippled Children, pp. 79-89.

Gielen, AC. & Sleet, D. (2003). Application of behavior-change theories and methods to injury prevention. *Epidemiologic Review*, 25, 65-76.

Gordon, JE. (1949). The Epidemiology of Accidents. *American Journal of Public Health*, 39 (Apr.), 504-515.

Haddon, W., Suchman, EA. & Klein, D. (1964). *Accident research: methods and* approaches. Harper & Row, New York.

Haddon, W. (1970). On the escape of tigers: An ecologic note (Strategy options in reducing losses in energy-damaged people and property). *Technology Review* (MIT) 72: 744-753, 1970; reprinted as an editorial, *Am J Pub Health*, 60 (12), 2229-2234.

Haddon, W. (1973). Energy damage and the ten countermeasure strategies. *J Trauma*, 13, 321-331.

Harel, Y., Overpeck, MD., Jones, DH., Scheidt, PC., Bijur, PE., et al. (1994). The effects of recall on estimating annual nonfatal injury rates for children and adolescents. *Am J Public Health*, 84, 599-605.

Hjort, PF. (1994). *Helse for alle. Foredrag og artikler 1974–93*. Oslo: Avdeling for samfunnsmedisin. (Utredningsrapport nr. U1 – 1994)

Holder, Y., Peden, M., Krug, E., et al. (Eds.). (2001). *Injury surveillance guidelines*. World Health Organization, Geneva. Available (2013-02-24) from: http:///www.who.int/violence_injury_prevention/index.html

Hägglund, M. (2007). *Epidemiology and prevention of football injuries*. Diss. Linköping University. LiU-Tryck, Linköping, Sweden.

International Mountaineering and Climbing Federation (UIAA). (2007). Statistics available (2013-02-24) from http://www.theuiaa.org/history.html

Jacobsson, J. (2012). *Towards systematic prevention of athletics injuries: Use of clinical epidemiology for evidence-based injury prevention*. Diss. Linköping University. LiU-Tryck, Linköping, Sweden.

Jacobsson, J., Timpka, T., Ekberg, J., Kowalski, J., Nilsson, S. & Renström, P. (2010). Design of a protocol for large-scale epidemiological studies in individual sports: the Swedish Athletics injury study. *Br J Sports Med*, 44, 1106-1111.

Johansson, A., Strömgren, M. & Backe, S. (2006). *Risk and safety management at Swedish municipalities*. MSB, Karlstad [In Swedish]. Available (2013-02-24) from https://www.msb.se/RibData/Filer/pdf/21580.pdf

Johnson, U. & Ivarsson, A. (2011). Psychological predictors of sport injuries among junior soccer players. *Scandinavian Journal of Medicine and Science in Sports*, 21, 129-136.

Jones, G., Asghar, A. & Llewellyn, DJ. (2007). The epidemiology of rock climbing injuries. *Br J Sports Med*, Published online December 7, 1-16.

Jones, MA., Hitchen, PJ. & Stratton, G. (2000). The importance of considering biological maturity when assessing physical fitness measures in girls and boys aged 10 to 16 years. *Annals of Human Biology*, 27, 57-66.

Karlberg, J., Lou, ZC. & Albertsson-Wikland, K. (2001). Body mass index reference values (mean and SD) for Swedish children. *Acta Paediatr*, 90 (12), 1427-1434.

Kelley, GA. (1998). Aerobic exercise and bone density at the hip in postmenopausal women. *Prev Med*, 27, 798-807.

Krustrup, P., Aagaard, P., Nybo, L., Petersen, J., Mohr, M., et al. (2010). Recreational football as a health promoting activity: A topical review. *Scand J Med Sci Sports*, 20 (Suppl. 1), 1-13.

Kucera, KL., Marshall, SW., Kirkendall, DT., Marchak, PM. & Garrett, WE. (2005). Injury history as a risk factor for incident injury in youth soccer. *Br J Sports Med*, 39, 462.

Lindqvist, K., Timpka, T. & Bjurulf, P. (1996). Injuries during physical activity in a Swedish municipality. *Scandinavian Journal of Social Medicine*, 24, 282-292.

Lund, J., Bjerkedal, T., Gravseth, HM., Vilimas, K. & Wergelund, E. (2004). A two-step medically based injury surveillance system: Experiences from the Oslo injury register. *Accid Anal Prevention*, 36, 1003-1017.

McHugh, MP. (2010). Oversized young athletes: A weighty concern. *Br J Sports Med*, 44 (1), 45-49.

McNoe, BM. & Chalmers, DJ. (2010). Injury in community-level soccer: development of an injury surveillance system. *Am J Sports Med*, 38 (12), 2542-2551.

Meeuwisse, WH. (1994). Assessing causation in sport injury: A multifactorial model. *Clin J Sport Med*, 4, 166-170.

Meeuwisse, WH. & Love, EJ. (1997). Athletic injury reporting: Development of universal systems. *Sports Med*, Sep: 24 (3), 186-204.

Micheli, L., Mountjoy, M., Engebretsen, L., Hardman, K., Kahlmeier, S., et al. (2011). Fitness and health of children through sport: the context for action. *Br J Sports Med*, 45, 931-936.

Mock, C., Acheampong, F., Adjei, S. & Koepsell, T. (1999). The effect of recall on estimation of incidence rates for injury in Ghana. *Int J Epidemiol*, 28, 750-755.

Moller, M., Attermann, J., Myklebust, G. & Wedderkopp, N. (2012). Injury risk in Danish youth and senior elite handball using a new SMS text messages approach. *Br J Sports Med*, Jun, 46 (7), 531-537.

Mountjoy, M., Andersen, LB., Armstrong, N., Biddle, S., Boreham, C., et al. (2011). International Olympic Committee consensus statement on the health and fitness of young people through physical activity and sport. *Br J Sports Med*, 45, 839-848.

Morrison, AB. & Schöffl, VR. (2007). Physiological responses to rock climbing in young climbers. *Br J Sports Med*, 41, 852-861.

National Board of Health and Welfare 2014a. *Cause of death register*. http://www.socialstyrelsen.se/statistics/statisticaldatabase/causeofdeath.

National Board of Health and Welfare 2014b. National Patient Register. http://http://www.socialstyrelsen.se/statistics/statisticaldatabase/inpatientcarediagnoses.

National Board of Health and Welfare 2014c. *Injury database Sweden online report*. http://www.socialstyrelsen.se/register/halsodataregister/patienregistret/idbsverige.

Neuendorf, KA. (2002). *The content analysis guidebook*, (pp. 1-25). Thousand Oaks, CA: Sage Publications.

Neuhof, A., Hennig, FF., Schöffl, I. & Schöffl, V. (2011). Injury risk evaluation in sport climbing. *Int J Sports Med*, Oct, 32 (10), 794-800.

Nilsen, P. (2006). *Opening the black box of community-based injury prevention programmes – Towards improved understanding of factors that influence programme effectiveness*. Diss. Linköping University. LiU-Tryck, Linköping, Sweden.

NOMESCO, Nordic Medico-Statistical Committee. (1997). *Classification of external cause of injuries, 3rd revision*. Copenhagen: NOMESCO.

O'Brien, J., Donaldson, A., Barbery, G. & Finch, CF. The three must-do's of intervention reporting: enhancing sport injury prevention research. *Br J Sports Med* 2013;**0**:1-3. doi:10.1136/bjsports-2013-092913

O'Connor, G., Hennekens, CH., Willett, WC., et al. (1995). Physical exercise and reduced risk of nonfatal myocardial infarction. *Am J Epidemiology*, 65, 1037-1045.

O'Donovan, G., Blazevich, AJ., Boreham, C., Cooper, AR., Crank, H., et al. (2010). The ABC of physical activity for health: A consensus statement from the British association of sport and exercise sciences. *Journal of Sports Sciences*, 28 (6), 573-591.

Orchard, J. (1995). Orchard sports injury classification system (OSICS). *Sport Health*, 11, 39-41.

Oxford Dictionary. (2014). Online definitions of sport. http://www.oxforddictionaries.com/definition/english/sport.

Paige, TE., Fioree, DC., Houston, JD. (1998). Injury in traditional and sport rock climbing. *Wilderness Environ Med*, 9, 2-7.

Petridou, E., Dessypris, N., Frangakis, CE., Belechri, M., Mavrou, A., et al. (2004). Estimating the population burden of injuries: A comparison of household surveys and emergency department surveillance. *Epidemiology*, 15 (4), 428-432.

Pieber, K., Angelmaier, L., Csapo, R. & Herceg, M. (2012). Acute injuries and overuse syndromes in sport climbing and bouldering in Austria: A descriptive epidemiological study. *Wien Klin Wochenschr*, 124, 357-362.

Price, RJ., Hawkins, RD. Hulse, MA. & Hodson, A. (2004). The Football Association medical research programme: An audit of injuries in academy youth football. *Br J Sports Med*, 38 (4), 466-471.

Puska, P., Tuomiletho, J. & Salonen, J. (1981). *The North Karelia Project: Evaluation of a comprehensive programme for control of cardiovascular diseases in 1972–1977 in North Karelia*. World Health Organization monograph series. Copenhagen: WHO.

Re-AIM.http://www.re-aim.hnfe.vt.edu/resources_and_tools/index.html (accessed July 2014)

Richmond, SA., Kang, J., Emery, CA. (2013). Is body mass index a risk factor for sport injury in adolescents? *Journal of Science and Medicine in Sport*, 16, 401-405.

Riksidrottsförbundet. (2011). Idrotten i siffror. Available (2014-09-23) from:

http://www.rf.se/ImageVaultFiles/id_44168/cf_394/2011_Idrotten_i_siffror_-_RF.PDF

Rothman, KJ. (2002). Measuring interactions. In: *Epidemiology: An Introduction*. New York, NY: Oxford University Press. (pp. 168-180).

Runyan, CW. (2003). Introduction: Back to the future – Revisiting Haddon's conceptualization of injury epidemiology and prevention. *Epidemiologic Reviews*, 25, 60-64.

Shanmugam, C. & Maffulli, N. (2008). Sports injuries in children. *British Medical Bulletin*, 86, 33-57.

Schiff, MA., Mack, CD., Polissar, NL., Levy, MR., Dow, SP., et al. (2010). Soccer injuries in female youth players: Comparison of injury surveillance by certified athletic trainers and internet. *Journal of Athletic Training*, 45 (3), 238-242.

Schweizer, A. (2012). Sport climbing from a medical point of view. *Swiss Med Wkly*, 142, w13688, pp. 1-9.

Schöffl, V., Morrison, A., Hefti, U., Schwarz, U. & Küpper, T. (2011). The UIAA medical commission injury classification for mountaineering and climbing sports. *Wilderness Environ Med*, 22, 46-51.

Schöffl, V., Morrison, A., Schöffl, I. Kupper, T. (2012). The epidemiology of injury in mounteneering, rock and ice-climbing. *Med Sport Sci*, 58,17-43.

Schöffl, V., Morrison, A., Schwartz, U., Schöffl, I. & Küpper, T. (2010). Evaluation of injury and fatality risk in rock and ice climbing. *Sports Med*, 40 (8), 657-679.

Selig, HF., Trimmel, H., Voelckel, WG., Hüpfl, M., Trittenwein, G., et al. (2011). Prehospital pediatric emergencies in Austrian helicopter emergency medical service – a nationwide, population-based cohort study. *Wien Klin Wochenschr*, Sep, 123 (17-18), 552-558.

Siesma, EJ. Blitvich, JD. White,PE. Finch,CF. (2011). Measuring children's self-reported sport participation, risk perception and injury history: Development and validation of a survey instrument. *J Sci Med Sport,* 14, 22-26.

Socialstyrelsen [The Swedish National Board of Health and Welfare]. (2003). *Statistics: Sports injuries among 7–19 years old people* [In Swedish]. Available (2014-09-23) from:

http://www.socialstyrelsen.se/Lists/Artikelkatalog/Attachments/10122/2005-125-12_200512512.pdf

Socialstyrelsen. (2010). Skadehändelser som föranlett läkarbesök vid akutmottagning: Statistik från Socialstyrelsens Injury Database (IDB) Sverige. [In Swedish] Available (2014-09-23) from: http://www.socialstyrelsen.se/publikationer2011/2011-11-18

Socialstyrelsen. (2011). Skador bland barn i Sverige: Olycksfall, övergrepp och avsiktligt självdestruktiv handling. [In Swedish] Available (2014-09-23) from: http://www.socialstyrelsen.se/publikationer2011/2011-2-13

Soderman, K., Adolphson, J., Lorentzon, R., Alfredson, H. (2001). Injuries in adolescent female players in European football: a prospective study over one outdoor soccer season. *Scand J Med Sci Sports*, 11 (5), 299-304.

Soligard, T. (2011). *Injuries in youth female football. Risk factors, prevention and compliance.* Diss. Norwegian School of Sport Sciences. Oslo, Norway.

Soligard, T., Grindem, H., Bahr, R. & Andersen, TE. (2010). Are skilled players at greater risk of injury in female youth football? *Br J Sports Med*, 44, 1118-1123.

Staff, T. & Søvik, S. (2011). A retrospective quality assessment of pre-hospital emergency medical documentation in motor vehicle accidents in south-eastern Norway. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 19, 20. Available (2014-09-23) from: http://www.sjtrem.com/content/19/1/20

Statistics Sweden 2014AA Online report. Tidsanvändningsundersökningen 2010,200 &1990. Http://www.scb.se/sv_/hitta-statistik-efter-amne/levnadsforhållanden.

Statistics Sweden 2014 BB. Online report. Tidsanvändningsundersökningen 2010,200 &1990. Http://www.scb.se/sv_/hitta-statistik-efter-amne/levnadsforhållanden.

Statistics Sweden 2014 CC. Online report. Tidsanvändningsundersökningen 2010,200 &1990. Undersökning av barns levnadsförhållanden. Http://www.scb.se/sv_/hitta-statistik-efter-amne/levnadsforhållanden.

Steffen, K., Pensgaard, AM. & Bahr, R. (2009). Self-reported psychological characteristics as risk factors for injuries in female youth football. *Scand J Med Sci Sports*, 19, 442-451.

Stratton, G., Reilly, T., Williams, AM. & Richardson, D. (2004). *Youth Soccer: From science to performance.* Routledge, USA.

Strömgren, M., Andersson R. (2010). The usage of safety management tools in Swedish municipalities. *Safety Science,* 48, 288-295.

Susser, M., Susser, E. (1996). Choosing a future for epidemiology: I. Eras and paradigms. *Am J Public Health*, 86, 668-673.

Svenskidrott. (2009). Idrotten vill – Idrottsrörelsens idéprogram. Available (2014-09-23): http://www.svenskidrott.se/ImageVaultFiles/id_37960/cf_394/IdrottenVill_2009_Webbversion.PDF

Svenska Klätterförbundet, SKF. (2005). [Swedish Climbing Federation]. Statistics [In Swedish] available (2013-02-24) from http://bergsport.se/klatterforbundet/om-klatterforbundet/historia/

Svenska Klätterförbundet, SKF. (2011). [Swedish Climbing Federation]. *Incidentrapporter 2011*. Bergsport, 150 (Jun), 35, page 37. Available at: http://bergsport.se/wp-content/uploads/2014/03/Bergsport_150_juni_2011.pdf

Swan, P., Otago, L., Finch, CF. & Warren, R.P. (2009). The policies and practices of sports governing bodies in relation to assessing the safety of sports grounds. *Journal of Science and Medicine in Sports*, 12, 171-176.

Swedish National Board of Health and Welfare. (1997). *The Swedish version of WHO's International Classification of Diseases, 10th revision* (ICD-10). Stockholm: Swedish National Board of Health and Welfare.

Tercero, F., Andersson, R., Peña, R., Rocha, J. & Castro, N. (2006). The epidemiology of moderate and severe injuries in a Nicaraguan community: a household-based survey. *Public Health*, 120, 106-114.

Timpka, T., Ekstrand, J. & Svanström, L. (2006). From sports injury prevention to safety promotion in sports. *Sports Medicine*, 36, 733-745.

Timpka, T., Finch, CF., Goulet, C., Noakes, T. & Yammie, K. (2008). Safe Sports International Board. Meeting the global demand of sports safety: the intersection of science and policy in sports safety. *Sports Medicine*, 38, 795-805.

Timpka, T., Lindqvist, K., Ekstrand, J. & Karlsson, N. (2005). Impact of social standing on sports injury prevention in a WHO safe community: Intervention outcome by household employment contract and type of sport. *British Journal of Sports Medicine*, 39, 453-457.

Twisk, JW. (2001). Physical activity guidelines for children and adolescents. A critical review. *Sport Med*, 31, 317-323.

Utmärkt förening. (2013). [In Swedish] Available (2014-09-23) from: http://www.falun.se/www/falun/ToF/fritid.nsf/doc/7D9F849C569252A1C12577B20030B8B9

Valuri, G., Stevenson, M., Finch, C., Hamer, P. & Elliott, B. (2005). The validity of a four week self-recalls of sports injuries. *Injury Prevent*, 11, 135-137.

van Mechelen, W., Hlobil, H. & Kemper, HC. (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Medicine*, 14 (2), 82-99.

van Mechelen, W. (1997). The severity of sports injuries. *Sports Medicine*, 24 (3), 176-180.

Villanueva, EV. (2001). The validity of self-reported weight in US adults: a population based cross-sectional study. *BMC Public Health*, 1, 11.

Waldén M. (2007). *Epidemiology of injuries in elite football*. Diss. Linköping University. LiU-Tryck, Linköping, Sweden.

Waller, JA. (1994). Reflections on a half century of injury control. *American Journal of Public Health*, 84 (4), 664-670.

Watson, WL. & Ozanne-Smith, J. (2000). Injury surveillance in Victoria, Australia: Developing comprehensive injury incidence estimates. *Accid Anal Prevention*, 32, 277-286.

Weber, RP. (1990). *Basic content analysis* (2nd Ed.). Newbury Park, CA: Sage Publications.

Wedderkopp, N., Kaltoft, M., Lundgaard, B., Rosendahl, M., Froberg, K. (1997). Injuries in young female players in European team handball. *Scand J Med Sci Sports*, 7 (6), 342-347.

Welander, G., Svanström, L. & Ekman, R. (2004). *Safety Promotion – an introduction* (2nd Ed.). Kristianstads Boktryckeri AB, Sweden.

WHO. (2003). Essential Public Halth Functions: A three-country study in the western pacific region.

WHO. (2009). *Milestones in health promotion: Statements from global conferences*. Geneva: World Health Organization.

WHO. (2010). *Global recommendations on physical activity for health*. Geneva: World Health Organization. Available (2013-02-24) from: http://www.who.int/dietphysicalactivity/publications/9789241599979/en/index.html

WHO and Pan-American health Organisation (2014). Essential public health function. Web based report. http://www.paho.org/hq/index.php?option=com_content&view=category&layout=blog&id=31756Itemid=3617.

Yang, J., Tibbetts, AS., Covassin, T., Cheng, G., Nayar, S., et al. (2012). Epidemiology of overuse and acute injuries among competitive collegiate athletes. *Journal of Athletic Training*, 47 (2), 198-204.

Yin, RK. (1994). *Case study research methods* (2nd ed.) (pp. 38-40). Thousand Oaks, CA: Sage Publications.

Ytterstad, B. (1996). The Harstad injury prevention study: The epidemiology of sports injuries. An 8 year study. *Br J Sports Med*, Mar; 30 (1), 64-68.

APPENDICES

Appendix A. Operationalization of study constructs

Table 2. Operationalization of study constructs

Construct	Measure	Comment
Gender	Female, male	Questionnaire item
Age	Full years	Questionnaire item
Age group	8-10, 11-12, 13-14, 15-18 years	Constructed variable. Used in some analyses.
Injury	Ordinal scale (1, 2-3, or ≥ 4 injuries)	Questionnaire item. The self-reported number of injuries during training and matches (during the study year). The answer was given on an ordinal scale (0 injuries, 1 injury, 2-3 injuries or ≥ 4 injuries).
Parents' educational level	High, low	Constructed variable. The formal education of the players' parents was asked for in the questionnaire. The highest formal education of the highest educated parent was used to define the level: High at least one parent with a university degree; low, otherwise.
Body mass index	z-height, z-BMI	Constructed variable. Self-reported height and weight were asked for in the questionnaire. Height and BMI were transformed into gender- and age-defined z-scores, i.e., number of gender- and age-specific standard deviations an individual differs from his/her gender- and age-specific means.
Self-reported health	Full health, low health	Constructed variable. Self-reported health was initially reported on a three-item scale. Full health, very healthy; low health, quite healthy or not very healthy.

Doi:10.1371/journal.pone.0043795.t001

Appendix B. Research questions and corresponding variables

Table 3. Research questions and corresponding variables

Research Question: Are injuries evenly distributed over…	**Variables introduced into analyses**
Q1… gender and age?	Injuries, gender, age group
Q2… gender, age and parents' educational level?	Injuries, gender, age group, parents' educational level
Q3… gender, age and body mass index?	Injuries, gender, age group, player body mass index (z-BMI, z-Height, z-Weight)
Q4… gender, age and self-reported health?	Injuries, gender, age group, self-reported health

For question 1, all interactions were of interest starting with the highest-order statistically significant interaction. For questions 2-5, the highest-order significant interaction was of interest, but only if it contained the injuries variable and the question-unique variable (in italics). Doi:10.1371/journal.phone.0043795.t002

Safety promotion and injury surveillance with special focus on young people´s club sports

Physical activity in youth has many benefits, but parallel to these benefits, sport related injuries pose considerable risks. It is important to public health to address sport related injuries, particularly those affecting young people, who comprise the majority of participants in organised sport in Sweden.

The first study in this research showed that inspections of local sport environments, where injuries often occur, did not occur uniformly. Two additional studies pointed out the need for better surveillance of injuries, and described the use of ambulance attendance reports as a possible improvement to current surveillance systems, with a possibility to improve safety for youth and other sport participants. Two other studies identify risk factors that were specific to football and climbing sports, which can be used to guide targeted safety interventions for the young participants of these sports.

The studies, taken as a whole, provide new information about the factors associated with sport related injuries, particularly for young people, and point out the need for better sport injury surveillance, improved inspection strategies for fields maintained by organised sport clubs in local communities, and the need to address risk factors specific to different sport activities.

ISBN 978-91-7063-601-1

ISSN 1403-8099

DISSERTATION | Karlstad University Studies | 2014:61