Towards systematic prevention of athletics injuries:
Use of clinical epidemiology for evidence-based injury prevention

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"If you are working on something exciting that you really care about, you don’t have to be pushed. The vision pulls you.”

Steve Jobs
Abstract

The aims of this thesis were to outline the design protocol for a prospective clinical epidemiological study of injuries among athletics athletes; study the 1-year prevalence, the point prevalence and incidence of injuries in total cohorts of Swedish elite adult and talented youth athletics athletes; pinpoint the risk indicators and factors for different injury types/patterns in athletics.

In *paper I*, an argument-based method to investigate complex design problems was used to structure the collection and analysis of data. A requirement analysis showed that a central requirement of an injury surveillance protocol for elite athletics should allow for detailed epidemiological analyses of overuse injuries, requiring self-reported data from athletes. The resulting study protocol was centred on a web-based weekly athlete e-diary enabling continuous collection of individual-level data on exposure and injuries.

In *paper II*, the prevalence of injuries was examined and 278 athletes (87%) of the enrolled study population submitted their assessments via the web survey. The overall 1-year retrospective injury prevalence was 42.8% (95% CI 36.9–49.0%). The point prevalence of ongoing injury was 35.4% (95% CI 29.7–41.4%). The 1-year injury prevalence showed a tendency to vary with regard to gender and age (p = 0.11). The diagnostic group that displayed the highest 1-year prevalence (20.9%, 95% CI 16.2–22.2%) and point prevalence (23.2%, 95% CI 18.4–28.7%) of injury was inflammation and pain with gradual onset.

In *paper III*, during the 52-week period, 292 athletes (91% of the study population) submitted weekly reports reporting a cumulative injury incidence of 3.57 injuries per 1000 hours of exposure to athletics. Most injuries (73%) were reported from training. There was a statistically significant difference with regard to gender and age in the proportion of athletes who avoided injury (P=0.043). Differences between event groups could not be statistically demonstrated (P=0.937). Ninety-six percent of the reported injuries were non-traumatic (associated with overuse). About every second injury (51%) was severe, causing a period of absence from normal training exceeding 3 weeks. Seventy-seven percent of the injuries occurred in lower extremities.

In *paper IV*, 199 (68%) athletes reported an injury during the study year. The median time to first injury was 101 days (95% confidence interval (CI) 75–127). Univariate log-rank tests revealed risk differences with regard to athlete category (p = 0.046), serious injury (>3 weeks time loss) during the previous season (p = 0.039) and training load rank index (TLRI) (p = 0.019). Athletes in the third and fourth TLRI quartile had almost a twofold increased risk of injury compared to the first quartile. Youth male athletes with a previous serious injury had more than a fourfold increased risk of injury compared with youth females with no previous injury.
List of papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals. Some unpublished results are also presented and are referred to as such.


Abbreviations

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

AE       Athlete exposure
CI       Confidence interval
EAA      European Athletics Association
HR       Hazard ratio
IAAF     International Association of Athletics Federations
ICD-9-CM Diseases of the Musculoskeletal System and Connective Tissue
IOC      International Olympic Committee
MA       Medical attention
MRI      Magnetic resonance imaging
na       Not available
NS       Not significant
P        Prospective
R        Retrospective
SAA      Swedish Athletic Association
SD       Standard deviation
TL       Time loss
TLRI     Training load rank index
TRIPP    Translating Research into Injury Prevention Practice
Introduction

One of the major challenges in competitive sports is to maintain fitness among the athletes. Maintenance of fitness means, in addition to preventing injuries, handling the injuries that still occur and rehabilitating the sportspersons in a safe way to prevent recurrence.

To be able to effectively plan these actions, the injury pattern in a specific sport has to be known. Systematic longitudinal injury surveillance has so far mainly been performed for team sports, e.g. ice hockey and football (1–3). Reports on the frequency of injuries in individual sports are rare (4–7).

In the 3 team sports, cricket, football, and rugby, injury consensus groups have formulated guidelines on how studies of injury epidemiology should be performed to allow comparisons between studies (8–10). Only one individual sport, tennis, has made a similar attempt (11).

The requirements for injury surveillance in team and individual sports have been reported to differ significantly with regard to the method and definitions of injuries (12–16). This makes it difficult to adopt outcomes from studies on team sports and implement them in athletics. The International Olympic Committee (IOC) injury research group (17) have developed recommendations for data collection in multisport events, such as the World Athletics Championships and the Olympics.

However, the contexts for longitudinal injury surveillance in team and individual sports such as athletics differ in several important aspects (Table 1). For example, there are important differences regarding everyday access to physicians and physiotherapists. In team sports, such as cricket and football, most of the elite clubs employ medical staff (16). It is therefore necessary to reflect on the main characteristics of team and individual sports to distinguish which components of injury surveillance in team sports are useful for the study of an individual sport.
Table 1. Conditions for elite athletes in selected team sports and athletics with relevance for the design of large-scale epidemiological studies (from Jacobsson J et al. Design of a protocol for large-scale epidemiological studies in individual sports. Br J Sports Med 2010;44;1106-11; with permission)

<table>
<thead>
<tr>
<th>Conditions for elite athletes</th>
<th>Soccer(^a)</th>
<th>Cricket(^b)</th>
<th>Rugby(^c)</th>
<th>Athletics(^d)</th>
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<td>Individual competition schedule</td>
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<td>✓</td>
<td>✓</td>
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<td>Medical staff employed by club</td>
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<td>Full professionals</td>
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</table>

\(^b\) cf. Orchard et al 2005.
\(^c\) cf. Fuller et al 2007.
\(^d\) Conditions for Swedish elite athletes

(✓)= few

Background

Athletics

Athletics is a popular sport worldwide and the governing body, the International Association of Athletics Federations (IAAF), represents 213 national athletic federations (http://www.iaaf.org) (football has 209 associations, http://www.fifa.com). A diverse range of sports are included under the umbrella of athletics; for example, race walking, cross-country running, marathon running and the 20 disciplines in the arena. In this thesis, it is these latter 20 disciplines that are the subject of investigation. Arena events can be further subdivided into 5 main categories: jumping, sprinting, throwing, middle/long distance running and combined events, and each subdivision consists of at least 4 disciplines. The training within each discipline is different but many of them include the same basic training with running (distance, sprint and interval), resistance training (free weights, medicine ball, etc.) and discipline-targeted techniques.

Swedish Athletics (SAA) has approximately 1000 registered clubs (http://www.friidrott.se), no license system (compared with, e.g. football). In Sweden the proportion within the age group 13–20 years participating in organized sports activities has been estimated to be 3% (http://www.rf.se). This ranks athletics as the 10th most popular sport in this age group and number 4 among individual sports with a estimated 15 000 athletes. The organization of athletics in Sweden follows the Nordic model of sport (18), in which participation in sports is primarily optional through membership in a club and attendance is on voluntary basis. Within this model, it follows that
most of the coaches involved do so on a freelance basis; some exceptions are the trainers employed by sports high schools and a few who train adult elite athletes. No medical staff are employed in Swedish Athletics at the federation or club level (Table 1).

International championships are organized on a regular basis by the international federations, European Athletics (EAA) and IAAF starting at the 17-year-old age group. Athletics has one indoor season (Sweden and the Northern Hemisphere) ending with an international championship for adults, usually at the beginning of March, and one outdoor season from about the end May until September. There are some variations in the seasons among the subgroups of events, for example, not all throwers have an indoor season and some of the middle/long distance runners also compete in cross-country races during the winter.

Considering athletics is such a widespread sport globally and was the largest at Olympics 2008, representing almost 20% of all participants (19), longitudinal cohort studies examining the risks and causes of injuries related to the sport are the exception. Since 2007, the IAAF has introduced routine data collection on injury incidence during the World Championships (20–22), adding data on illness from 2009, and jointly with the IOC during the Olympics in Beijing 2008 (19).

There is no routine documentation in place for injury patterns in Swedish athletics at national level or at club level, and to our knowledge the situation is no better in other countries. It is therefore deeply disquieting that scientific epidemiological studies of injury incidence and patterns in athletics are scarce, for both adolescents and adults (23–26). Moreover, the studies that are available lack uniformity in methods and the definitions of athletics injuries varies, this makes it difficult to compare the results between studies and to allow injury patterns to be generalized over athletic populations.

What is known about injuries in athletics?

Studies on athletics display non-uniformity of settings, for example, a region in a country (27, 28), display one discipline (29, 30), injuries treated in hospitals (31), clubs (32), high-level competition (20–22) and school settings; the latter are mainly presented in merged data with various sports (33–36). Moreover, only the most recent published articles, covering international championships, have included all arena disciplines in athletics (20–22).

Most commonly used definition of injury in the sport has been based on time-loss from participation in athletics exceeding 1 day (29), miss > 2 practise sessions (24) or 1 week (27, 28). In competitions have the suggested definition by IOC (17), displaying both time-loss and medical attention (19, 20, 21, 22),
been used. A few studies have reported injuries as when the athlete needed medical care i.e. medical attention (23).

**Injury incidence**
The risk for injury is relatively high in athletics populations representing geographic areas. An annual injury incidence ranging between 65 and 75% (27, 28) has been reported. Data from adult high-level competition, World Championships and the Olympics display a cumulative injury incidence close to 10% per occasion (19–22). To enable the risk for injury to be estimated, measures of exposure, e.g. time when the athlete is taking part in the sport, must be considered (15, 37). It is recommended that exposure is presented as the number of injuries per 1000 hours of participation, preferably collected on an individual basis (38). In athletics, only 3 studies were found to correspond with these criteria (27–29) and one had made an estimate of exposure (39). Together they show an incidence ranging from 2.5 to 7.1/1000 h of exposure; the remaining studies present incidence per athlete (Table 2). Three studies reported that most injuries occurred during training sessions (24, 25, 28).

**Injury localization, type and severity**
The proportions of all injuries in the different studies are presented in Table 3, which shows that the lower extremity is the most affected body region (range 75–95%). These injuries are relatively evenly distributed between the 3 regions of the lower limbs (Table 3). Some studies report that close to 15% of all injuries occur in the vertebral column (25, 29). Very few injuries have been reported for the upper extremities; this might partly be explained by the fact that a limited number of studies have included all athletics disciplines.

The athletes in athletics seem to mainly sustain injuries related to overuse. Commonly reported diagnosis are muscle strains (hamstrings most frequent), sprains (typically ankles), tendopathies (usually Achilles, patellar), stress fractures and other overuse-related conditions such as shin splints (Table 3). Injury types have shown a tendency to differ between disciplines, for example, sprinters have more sudden onset injuries and long distance runners have gradual onset injuries (27, 28).

The severity of injury in sports is usually reported as the time lost from participation. Due to the limited number of studies on athletics reporting exposure, little information is available in this field. The only study that reported lost training time is by Bennell and Crossley (28). They reported that athletes did not return to full training until approximately 9 weeks after injury onset.

**Risk factors**
The aetiology of sports injuries is multi-factorial by nature (40), consisting of interacting intrinsic as well extrinsic risk factors (41). The literature on athletics is ambiguous regarding the risk factors associated with injuries. The limited number of studies published, shifting methodologies and the definitions used for data collection may possibly explain this. Furthermore, the results from
some of the older studies on athletics need to be interpreted with caution, as it sometimes unclear which statistics were used for risk factor analysis.

D’Souza (25) found that older age (> 20 years) was associated with an increased risk for injury and Bennell and Crossley (28) reported that older age (> 20.5 years) was a risk factor for sustaining multiple injuries. The relationship between gender and injury has shown conflicting results. Three studies could not show any association (25, 27, 28), whereas Alonso et al (21, 22), in analyses of data collected in association with the IAAF World Championships, found a higher injury risk for men than for women. No studies have reported any differences in the risk for injury between event groups or found any association with anthropometrics. Bennell and Crossley (28) showed that greater flexibility and menstrual disturbance were associated with injury risk, but no other studies have presented similar results. Bennell et al (42), in a study of stress fractures, showed, using multivariate statistics, that age of menarche and calf girth were significantly associated with increased risk for stress fractures in women.

Two studies, Orava (23) and Lysholm and Wiklander (27), indicated an association between training routines and risk for injury. In contrast, Bennell and Crossley found no such association. However, in the study by Lysholm and Wiklander, these risk factors were only analysed in injured athletes. No comparisons were made between injured and non-injured athletes. In one study, unsupervised training has been shown to increase the risk for injury (25). A history of previous injury has been associated with sustaining a new injury in competitions (20, 22) and Rebella et al (29), using a multi-variable approach, reported a twofold risk for previously injured athletes.
Table 2. Injury incidence in athletics. Only prospective studies that account for arena events are included.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Design</th>
<th>Country, setting</th>
<th>No of athletes, gender</th>
<th>Age</th>
<th>Study period</th>
<th>Injury definition</th>
<th>Injury incidence</th>
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<tr>
<td>Alonso et al 2009</td>
<td>P</td>
<td>Japan, 2007 World Championships, all events</td>
<td>1980 M: 1031* F: 943*</td>
<td>Adult</td>
<td>10 days</td>
<td>TL, MA</td>
<td>97.0/1000 registered athletes</td>
</tr>
<tr>
<td>Junge et al 2008</td>
<td>P</td>
<td>China, Beijing, 2008 Olympics, all events</td>
<td>2132 M: 1193* F: 945*</td>
<td>Adult</td>
<td>10 days</td>
<td>TL, MA</td>
<td>113/1000 registered athletes</td>
</tr>
<tr>
<td>Alonso et al 2010</td>
<td>P</td>
<td>Germany, 2009 World Championship, all events</td>
<td>1979 M: 1301* F: 1077*</td>
<td>Adult</td>
<td>10 days</td>
<td>TL, MA</td>
<td>135.4/1000 registered athletes</td>
</tr>
<tr>
<td>Alonso et al 2012</td>
<td>P</td>
<td>South Korea, 2011 World Championship, all events</td>
<td>1851 M: 1063* F: 964*</td>
<td>Adult</td>
<td>10 days</td>
<td>TL, MA</td>
<td>134.5/1000 registered athletes</td>
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<td><em>Club/region</em></td>
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<tr>
<td>Orava et al 1978</td>
<td>P</td>
<td>Finland, region, events na</td>
<td>48 M: 26 F: 22</td>
<td>10–15</td>
<td>2–3 years</td>
<td>TL, MA</td>
<td>148/100 athletes</td>
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<tr>
<td>Zaricznyj et al 1980</td>
<td>P</td>
<td>USA, region, events na</td>
<td>289 children</td>
<td>5–17</td>
<td>1 year</td>
<td>MA</td>
<td>5.7/1000 h participation (estimated by author)</td>
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<tr>
<td>Lysholm and Wiklander, 1987</td>
<td>P</td>
<td>Sweden, club, runners Events - sprint, middle and long distance</td>
<td>60 M: 44 F: 16</td>
<td>16–42</td>
<td>1 year</td>
<td>TL &gt; 1 week</td>
<td>2.5 – 5.8/1000 h training</td>
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<tr>
<td>Bennell et al 1996</td>
<td>P/R</td>
<td>Australia, region All events except throws, pole vault</td>
<td>95 M: 49 F: 46</td>
<td>17–26</td>
<td>1 year</td>
<td>TL &gt; 1 week</td>
<td>3.9/1000 h training</td>
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<tr>
<td><em>School setting</em></td>
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<tr>
<td>Watson and DiMartino 1987</td>
<td>P</td>
<td>USA, high school All events except throws, long jump</td>
<td>234 M: 156 F: 78</td>
<td>14–18</td>
<td>77 days</td>
<td>TL &gt; 2 practice sessions or 1 meet</td>
<td>17.5/100 athletes</td>
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<td>Rebella et al 2008</td>
<td>P</td>
<td>USA, high school, pole vault</td>
<td>140 M: 76 F: 64</td>
<td>15–17</td>
<td>Two seasons; length of season not defined</td>
<td>TL &gt; 1d or MA</td>
<td>7.1/1000 athlete exposure</td>
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*Reported in paper, not sum of athletes because some competed in more than one discipline. TL, time loss; MA, medical attention,
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<td>Upper</td>
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<td>1.8</td>
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<td>32</td>
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<td>17.8</td>
<td>17.6</td>
<td>32.3</td>
<td>22</td>
<td>41.8</td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>20.5</td>
<td>–</td>
<td>2.6</td>
</tr>
<tr>
<td>Sprain, strain, rupture</td>
<td>31.2</td>
<td>27.1</td>
<td>52.8</td>
<td>21</td>
<td>–</td>
<td>25.5</td>
<td>–</td>
<td>30</td>
<td>34.1</td>
<td>57.9</td>
</tr>
<tr>
<td>Joint derangement</td>
<td>0.5</td>
<td>0.7</td>
<td>1.2</td>
<td>1.5</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>5.3</td>
</tr>
<tr>
<td>Fracture</td>
<td>0.5</td>
<td>0.4</td>
<td>0.8</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.6</td>
</tr>
<tr>
<td>Open wound, laceration</td>
<td>17.2</td>
<td>17.4</td>
<td>9.6</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Dislocation</td>
<td>1</td>
<td>0.4</td>
<td>0.4</td>
<td>1</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.6</td>
</tr>
<tr>
<td>Contusion</td>
<td>8.3</td>
<td>7.4</td>
<td>7.2</td>
<td>3</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>18.4</td>
</tr>
<tr>
<td>Internal, nerves</td>
<td>1.6</td>
<td>0.4</td>
<td>0.4</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Others, multiple</td>
<td>9.4</td>
<td>11.8</td>
<td>2.0</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>13.3</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

P, Prospective; R, Retrospective.

*Exact body location not available. All data calculated from data presented in articles.
Prevention of sports-related injuries

The need for a sports epidemiology evidence base as a foundation for planning of preventive interventions is uncontested. Guidelines on how to conduct injury prevention measures in sports have been described in the literature by van Mechelen et al (38) in a model consisting of 4 steps: (1) find out the extent of the problem in the sport investigated; (2) establish the causes; (3) introduce preventative measures; and (4) assess their effectiveness by repeating step 1. Recently, Finch (43) has recommended extending this model with additional steps, into the The Translating Research into Injury Prevention Practice (TRIPP) paradigm. The TRIPP model emphasizes the necessity of understanding how research findings are applicable and translated in the real world, that is, increase understanding on how the actions suggested will be accepted and implemented by the sport being investigated. In several individual sports, such as athletics, this body of fundamental research (steps 1 and 2) is lacking in general populations. To try to overcome this shortcoming, it is necessary to analyse and evaluate the inter-national variations within the organization and performance of athletics as an elite and community sport (Table 4).

Injury surveillance in athletics is called for from 2 perspectives, that is, the national sports organization perspective (44) and from the view of the individual sportsperson. However, only the national sports organizations have the mandate to systematically establish and introduce preventative measures for those participating in the sport. Future injury prevention in athletics will possibly, as in other sports, address separate issues in the different subgroups of events, between sexes, age groups, etc. This includes, for example, taking into consideration both the physical and behavioural maturation of the child and how this maturation is associated with the development of injuries in the near future and later on in the sporting career. Competing with the best athletes at both national and international level is today not only a goal for adult athletes, it is also a part of the youth athlete’s ambitions. The youth elite athlete can invest years of training in a sport and a promising career can be abruptly ended due to an injury caused by lack of scientific knowledge about injury risks and mechanisms. The IOC (45) emphasize the importance of incorporating scientific research in finding safe ways to effectively train elite children and adolescents. The temporal pathogenesis model implies that many common load-induced musculoskeletal conditions that restrict performance among elite athletic athletes can be prevented by timely adjustment of practice schedules or medical interventions (46). This highlights the importance of including talented youth athletes when conducting surveillances studies in a given sport. The use of web-based technology might be one way to reach these age groups in an individual sport such as athletics in countries where the technology infrastructure is available.
Table 4: Possible national-level variations in the organization of athletics that may affect the design of injury surveillance, risk factors for sustaining injuries as well as future implementation and dissemination of preventative measures.

<table>
<thead>
<tr>
<th>Economy</th>
<th>National federation</th>
<th>Coaches employed/leisure/freelance</th>
<th>Medical accessibility</th>
<th>Athletes individually supported by sponsors and/or national sports federations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culture</td>
<td>Residential conditions, i.e. living in home cities/educational cities/sports centres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology infrastructure</td>
<td>e.g Internet usage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate</td>
<td>Northern vs southern Europe, Northern Hemisphere vs Southern Hemisphere. Seasonal differences</td>
<td>Indoor/outdoor seasons</td>
<td>Outdoor tracks are 400 m vs indoor (usually 200 m, often with banked curves to compensate for tight radius)</td>
<td>Arena track (mondo, grass)</td>
</tr>
</tbody>
</table>

Prospective clinical epidemiological studies (47) that allow detailed identification of individuals and groups at risk are warranted to evaluate the thin line between functional over-reaching and overtraining leading to overuse injuries (48, 49) and to distinguish hazardous environments. The frequent occurrence of overuse-related injuries in the sport indicates that injury surveillance studies in athletics cannot depend only on injury data reported by general practitioners, physiotherapy clinics or hospital data.

Alternatives options and solutions need to be considered and developed for routine collection of data from these difficult to target groups of athletes to describe the extent of musculoskeletal injuries. Due to the limited epidemiological base in athletics, little knowledge exists on the short-term impact as well as the long-term impact of injuries sustained. The resulting knowledge could immediately support the planning of injury prevention at primary (preventing injury), secondary (preventing manifest injuries developing into chronic conditions), and tertiary levels (evading performance limiting consequences from chronic conditions) in a national population of elite athletics athletes (50).
Aims of the study

The aims of this thesis project were to:

Outline the design protocol for a prospective clinical epidemiological study of injuries among athletes competing at the highest national level in field event athletics (paper I)

Define athletic injury and its different dimensions (paper I)

Evaluate the one-year prevalence and point prevalence in total cohorts of Swedish adult elite and youth talent athletics athletes (paper II)

Evaluate the incidence and contexts of injury events in 2 cohorts of Swedish adult elite and youth talent athletics athletes (paper III)

Pinpoint risk indicators and factors for different injury types/patterns in athletics (paper IV)

Based on the results, formulate principles for an evidence-based injury prevention and safety promotion program for athletics
Subjects and methods

Design of the studies

This thesis includes 4 papers. The first study used an argument-based method to develop a study protocol. Papers II–IV used an observational epidemiological design (Figure 1). Study II used a cross-sectional survey to assess the prevalence of injuries in 2 cohorts: adult and youth athletes. Studies III and IV used a prospective design to describe the incidence of injuries in the same cohorts, using a descriptive approach (study III) and an analytical approach (study IV). The STROBE guidelines for reporting of observational epidemiological studies were applied (51).

![Figure 1. Temporal aspects of data collection](image)

Development of the study protocol (paper I)

This study used an argument-based method for the rational solution of design problems (52, 53) to structure the collection and analysis of the data. Briefly, the purpose of an argument method is to specify arguments for specific solutions. Realization of a study design was preceded by an examination of the requirements for injury surveillance in individual sports and drafting of specifications. The ambition was to maintain compatibility with previous studies in high-level team sports, that is, to distinguish what is common in studies on team sport and what features are difficult to adopt and implement in athletics.
Data collection

A nominal group method (54) was used for the requirements analysis. This is a structured method for making decisions; it is relatively quick and involves small groups so that every member’s opinion is taken into account. Two expert panels examined the requirements of the data to be collected and implementation of the study in practice. Individual experts reviewed a working document on the requirements followed by telephone discussions. Requirements of the data to be collected were defined by a panel consisting of scientists and practitioners (n = 8) with backgrounds in athletics coaching, sports medicine, epidemiology, and medical psychology. The panel examining the requirements for implementation of the study in practice consisted of scientists (n = 5) with backgrounds in sports medicine, biostatistics, health informatics, and cognitive science. To enhance communication, there was an overlap of members in the 2 groups. The experts provided a first round of comments to the study coordinator, who assembled these into a case study assessment document. When subsequent rounds did not return significant changes in the document, the requirement specifications were considered established. The agreements are shown with the other results in the Results section. In addition, to answer specific questions (e.g. on injury definition, data collection procedures), international experts were consulted during a working seminar at the 2nd World Congress on Sports Injury Prevention in Tromsø in 2008.

Design of the study protocol

Data from the two-step requirements analysis processes were transferred to a study design specification procedure. Members of the 2 panels were merged into one design specification group. The task communicated to the group was to formulate functional study protocol solutions using the requirements, their subject matter expertise, and the published literature. The experts first provided their individual comments, which were collected by a design process coordinator. The experts formulated suggestions for the study protocol independently. Comments on each version of the working document on the study design were subsequently circulated to the entire expert group and a consensus document was established. In the third and final step, the design was accepted as a prototype study protocol.

Evaluation of the study protocol

A heuristic cognitive walkthrough (55) (a method used to identify usability issues by learning the task by implementing it) of the preliminary injury surveillance part of the protocol was performed. A group of reviewers (n = 6)
were each asked to go through the questions individually with 6 user setting scenarios in mind: (a) have been injured, but now recovered; (b) have been healthy, and still healthy; (c) have been injured, and still injured; (d) have been healthy, but now injured; (e) have been injured, but now recovering with adjusted workload; (f) entering the study with a previous injury. The reviewers were asked to answer the questions (i) if there were any ambiguities or vague formulations; (ii) if there was a lack of suitable alternatives, or (iii) if there was any risk of misinterpretation and what the consequences of these observations would be. The reviewers’ reports were then summarized and analysed by an experienced design group (n = 3) and formulated as change measures. Examples of changes included ambiguity in the injury report form where the alternatives for estimated absence due to injury were limited; an athlete injured for 2.5 weeks had to choose between the <2 weeks or 3–4 weeks (unpublished results).

Pilot study

The final evaluation of the prototype injury surveillance protocol was performed using a pilot study among adult and youth athletes (n = 22). The prototype protocol was used for injury surveillance during a 3-week period followed by a questionnaire survey. The evaluation of the pilot study generated in 14 additional change measures (unpublished results). Most of the adjustments (9) were made in the weekly report form where the emphasis was on making the order of questions functional; for example, 2 questions changed places in the final version and additional alternatives were provided for reasons “why not training as planned” with examples in brackets: reason “infection” (cold, sore throat, etc.). Clarification was also requested in the weekly e-mails alerts (substance box) to specify actual dates of data collection (not just the week number). In the other instruments, the changes involved clarifying the injuries reported. The survey data were analysed and the prototype protocol was revised into the final protocol version.

The design protocol was then implemented in a study conducted among adult elite and youth talent athletics athletes in Sweden (papers II–IV).
Injury surveillance (papers II–IV)

Overview of research design

Study II used a cross-sectional design. Data were collected in April 2009 via a web-based questionnaire assessing self-reported injury data from the athletes. Studies III and IV were based on prospective epidemiological data collected from 2 cohorts over a 12-month period from March 2009 until March 2010. Study III used a descriptive approach and study IV used an analytical approach.

Subjects

The subjects were recruited if, at the end of October 2008, they were ranked among the top 25 on the national ranking lists for athletics. The Swedish Athletic Association keep statistics for the top 25 adult athletes, both outdoor and indoor, for each discipline and these lists are updated throughout the season. For adolescents, there are national statistics for the top 20 in 18 field events (http://www.friidrott.se). To make contact with a high number of athletes who might be interested in taking part in the study, we aimed to contact “unique” top 10 athletes in each discipline, both adult and youth aged 16 years in 2008. The definition of “unique” in this context meant that an individual athlete could only be on one ranking list (i.e. one discipline).

The top 10 lists, 4 in total (2 adult men/women and 2 youth boys/girls), were managed by the technical director at the Swedish Athletic Association. The lists were put together in the same way for all groups and an athlete was included if they were ranked in the top 10 of the top 25 (or of the top 20 for youth athletes). If an athlete was ranked among the top 10 in more than one discipline (e.g. ranked number 2 in 2 disciplines), the athlete was added to the top 10 list of what was considered to be their main discipline. That athlete was then excluded from the second event and the athlete ranked number 11 on the top 25 list was added to the top 10 list, and so on. In both cohorts, 10 athletes were not always recruited mainly because many athletes compete in multiple events; this was especially common among youths. Among the men, the long jump ended up with 8 athletes; among the women, the 200 metres only got 7 athletes. Among the youth, 7 disciplines for girls and 12 disciplines for boys did not reach 10 top athletes (unpublished results).
Recruitment

Postal addresses for the adult group were obtained from the SAA, and if unavailable, from the athlete’s local club. For the youth athletes, no such central register exists. Their addresses were collected from a web site listing contact information for most Swedish citizens (http://www.upplysning.se, Berlock Information AB i Enköping, Sweden). If not found on this web site, e-mails were sent to the athletes’ clubs. Invitations were sent by post from December 2008 to January 2009 with one reminder in February 2009. Letters were sent to 649 eligible athletes (367 adults and 282 youths) with information about the study and an answer sheet and prepaid envelope. They were asked to return the envelope with their answer whether they were interested in taking part in the study or they declined to participate. For the youths whose addresses were not identified and for the non-responders, a letter (addressed to the athlete, \( n = 55 \)) containing the same information about the study was added to the information sent to the clubs competing at the Swedish youth indoor championships in March 2009. To finally be confirmed eligible for the 1-year prospective study, the athletes had to consider themselves active, injured or not, at the start at the study.

Amongst the 649 potential athletes, 10 athletes were found to be not eligible to the 1-year study due to retirement from athletics. Thus, 639 athletes (361 adults, 278 youth) were invited to participate in the study and 72% (\( n = 461 \)) responded. Seventy percent (\( n = 321 \)) consented to participate in the study. The final study population thus included 321 individuals, 50% of the final eligible population.

Data collection

Data were collected using a combination of a web-based injury surveillance system and a postal survey. The overall dilemma in conducting injury surveillance studies in an individual sport such as athletics is how to collect the necessary data. In this study, we introduced a web-based electronic weekly athlete’s diary to try to overcome the difficulties in collecting continuous information (i.e. hours of training/week). The athletes did all the recording themselves (with parental guidance for those less than 18 years of age). This required a substantial degree of commitment from each athlete and our aim with the instruments was to make them take up as little time as possible while still being sensitive. Other alternatives for collecting data were considered, such as asking coaches for assistance with the documentation but most adult athletes, regardless of their level of performance, do a program of training sessions without supervision. We also considered was having a local physician/physiotherapist on site on a weekly basis but this was ruled out as not feasible mainly due to the irregularity in training times and training sites.
Table 5. Summary of the definitions used in this thesis

<table>
<thead>
<tr>
<th>Used in papers</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reportable sports injury II</td>
<td>A musculoskeletal condition such that the athlete partially or completely abstained from training or competition in athletics.</td>
</tr>
<tr>
<td>Point prevalence II</td>
<td>At the time of the survey.</td>
</tr>
<tr>
<td>One-year retrospective prevalence II</td>
<td>For a minimum injury period of 3 weeks (compromising injury) during the past year.</td>
</tr>
<tr>
<td>Reportable sports injury III, IV</td>
<td>Any NEW musculoskeletal pain, soreness or injury that resulted from athletics training or competition that caused alterations in normal training/competition in mode, duration, intensity or frequency from the current or subsequent training and/or competition sessions (partial time loss injury) OR Any NEW musculoskeletal pain, soreness or injury that resulted from athletics training or competition and required complete absence from the current or subsequent training and/or competition sessions (time loss injury).</td>
</tr>
<tr>
<td>First injury III, IV</td>
<td>Initial injury occurring during the study year, also defined as the index injury.</td>
</tr>
<tr>
<td>Subsequent injury III</td>
<td>Injury occurring after the first injury, if not in the same location and of the same type as the previous injury.</td>
</tr>
<tr>
<td>Recurrent injury III</td>
<td>Injury occurring in the same location, of the same type, and reported to have occurred within 2 months from a previous similar injury.</td>
</tr>
<tr>
<td>Injury severity III, IV</td>
<td>Absence from normal athletics training/competition for 1–3 days, 4–7 days, 8–20 days, &gt;21 days.</td>
</tr>
<tr>
<td>Overuse Injury II, III, IV</td>
<td>A condition, with a gradual or sudden onset, resulting from repeated microtrauma without a single identifiable event responsible.</td>
</tr>
<tr>
<td>Traumatic Injury II, III, IV</td>
<td>A condition caused by one identifiable event.</td>
</tr>
<tr>
<td>Incidence III, IV</td>
<td>A NEW event according to the definition of sports injury.</td>
</tr>
<tr>
<td>Training exposure III</td>
<td>Individual physical activities related to training in athletics including warm up and cool down.</td>
</tr>
<tr>
<td>Competition exposure III</td>
<td>Individual physical activities related to and including competition in athletics including warm up and cool down.</td>
</tr>
</tbody>
</table>

**Injury definitions**

In study II, for the 1-year retrospective prevalence measure, an athletics injury was defined as a musculoskeletal condition that made the athlete partially or completely abstain from training or competition in track and field for a 3-week minimum injury period during the past year, that is, retrospective 1-year
prevalence. For the point prevalence measure, an athletics injury was defined as a musculoskeletal injury at the time of the survey. In studies III and IV, the athletes were asked to report as follows: “A partial time loss injury is any \textit{new} musculoskeletal pain, soreness or injury that resulted from athletics training or competition and caused \textit{alterations} in normal training/competition in mode, duration, intensity or frequency from the current or subsequent training and/or competition sessions” and “A time loss injury is any \textit{new} musculoskeletal pain, soreness or injury that resulted from athletics training or competition requiring \textit{complete absence} from the current or subsequent training and/or competition sessions” (Table 5).

Data collection instruments (papers II, III, IV)

A secure web site for collection of data on exposure to athletics training and competition as well as injury surveillance was developed. This is a standard web tool that uses usernames and passwords to protect data from unauthorized use (SiteVision v2.5, Senselogic AB, Örebro, Sweden).

Baseline form (papers II, III, IV)

Baseline data were collected via a web-based document using a questionnaire on demographics and subject characteristics (i.e. sex, age, height, weight, experiences from participation in athletics, major event/discipline and previous injuries) (see Appendix 1). Due to the setup of the study, it was not possible to collect detailed information about individual anthropometrics or any biomechanical data.

Electronic weekly athlete diary (papers III, IV)

Data on athletics training and competition as well as injury surveillance were collected in a weekly athlete diary that was assessed using the web questionnaire/diary (Appendix 1). E-mails were sent automatically on a weekly basis to participants with questions about the previous week on the amount of training/competition hours and occurrence or absence of injury; one reminder was sent to those who did not respond. The following information was collected in the diary: (a) whether fully training or not; (b) hours of training and competition; (c) frequency of training occasions; (d) weekly training intensity; (e) any medical contact; (f) well-being; and if injured the athlete was asked to report on (g) type of training (e.g. rehabilitation training, modified athletics training, etc.); and (h) number of training sessions missed.
All weekly reports were monitored on a weekly basis by 2 of the researchers (JJ and TT) to follow the injuries reported. If an athlete was absent from training due to a reported injury lasting for a period of more than 3 weeks, this was followed up by an email by one researcher (JJ). When injury-related problems, as defined above, kept the athlete from returning to full training within 3 weeks, the athlete was requested to get examined by a sports physician or sports physiotherapist to confirm a full clinical diagnosis.

**Injury report form (papers III, IV)**

An injury was reported first in the weekly web registration. The injured athlete was then linked automatically to the injury report document where further questions about the current injury were asked (Appendix 1). The instrument used for injury surveillance is an extended version of the injury report form originally developed by the soccer consensus group and IOC group (9, 17), and adjusted to a web format. This injury report form was shown to be feasible for individual sports during competition at the World Championships in athletics in Osaka in 2007 (20) and was used for individual sports during the Olympics in Beijing in 2008 (19). However, we extended it further to enable it to be used specifically for athletics for both competition and training. The original injury report form (17) was translated from English to Swedish using a back-translation procedure (56). All the original questions were included in our injury report form and additional questions were asked regarding (a) when the injury occurred (i.e. training/competition indoor/outdoor), (b) details of the training method performed at the time of injury (e.g. interval, weight, sprint, etc.), (c) site of injury (e.g. left/right, back/front), (d) who made the preliminary diagnosis (e.g. trainer, medical profession, parent, etc.) and (e) whether the athlete had had the same injury previously.

**Injury closure form (papers III, IV)**

When the athlete returned to normal athletics training, they were sent a closure form about the reported injury with questions about (a) date when back to fully training, (b) the final diagnosis, (c) information about who made the diagnosis and (d) kind of treatment received. Further personal remarks about the reported injury could be added to a comment box (Appendix 1).

The web questionnaire were tested for 3 weeks in 2 pilot studies, covering both adult and youth athletes ($n = 22$), and was found to be understandable and valid for this purpose.
Categorization and classification of injuries (papers II, III, IV)

To categorize the coded injury data according to injury type (nature of the injury) and anatomic location (body region), a matrix adjusted to athletics injuries from Hauret et al’s (57) original classification for diagnoses in Chapter 13 of the ICD-9-CM (Diseases of the Musculoskeletal System and Connective Tissue) was developed. Injury categories are identified in the matrix by column headings. Rows represents categories “non-traumatic injury” and “traumatic injury” at the highest level. In Hauret’s matrix, traumatic injuries included diagnoses from Chapter 17 of the ICD-9-CM (Injury and Poisoning). These diagnoses included acute traumatic injuries with sudden discernable effects. In our version of the matrix, the traumatic injury diagnoses were structured according to Barell’s matrix for categorization of traumatic injuries (58). Therefore, an additional row was inserted to divide non-traumatic injuries into those with sudden and gradual onset. The third row of the adjusted matrix displays the injury diagnosis groups according to Hauret and Barrel’s matrices. The modified matrix included only those ICD-9-CM codes for injuries reported in our study; we made no attempt to categorize all possible diagnoses that could occur in athletics. Inflammation and pain (gradual onset) included injuries characterized by inflammation and/or pain (e.g. low back pain (code 724.2), patellar tendinitis (code 726.64), medial tibial stress syndrome (i.e. shin splints, code 844.9) and Achilles tendinitis (code 726.71)) due to physical damage resulting from low magnitude forces (microtrauma). The second group included stress fractures (gradual onset); common stress fractures occur in the tibia (code 733.93) and metatarsals (code 733.94). The third group, sprain/strain/rupture (sudden onset), included injuries with sudden onset due to acute trauma, possibly in combination with preceding cumulative microtrauma (e.g. thigh strains (code 843) or ankle sprains (code 845)). The fourth group, joint derangement (sudden onset) included conditions involving joint derangement or dislocation with and without neurologic involvement. These injuries result from traumatic forces, sometimes in combination with preceding cumulative microtrauma, and include meniscal tears of the knee (codes 717.0–717.5), articular cartilage disorders (i.e. chondromalacia patella (code 717.7)), intervertebral disc disorders of the cervical (code 722.0) or lumbar spine (code 722.1). The last group, “other and unspecified,” consisted of injuries that are hard to classify for a specific body region from their ICD-9-CM diagnosis codes.

A group consisting of 1 physiotherapist and 3 physicians with a background in sports medicine classified all self-reported injuries/diagnoses in studies II to IV into a three-digit diagnostic code (ICD-9-CM). Before the reported injuries were classified, the injury data were verified according to the study protocol and irregularities were removed; for example, only injuries that had occurred during the study period (30 March 2009 to 28 March 2010) should be included and injuries that happened outside athletics (e.g. during school gymnastics) should be excluded. The physiotherapist (JJ) and one physician
(SN) independently assigned a preliminary coding and if there was any
disagreement, this was a subject for clarification. The definitive list was then
reviewed by the 2 remaining physicians (PR, TT).

In paper IV, we made an attempt to quantify the training load on a weekly
basis by adding a training load rank index (TLRI) (59) combining training
hours and intensity on a relative basis. The TRLI variable defining the relative
training load was constructed by multiplying the reported training intensity
(light = 2, moderate = 3, hard = 5) reported for the week with the number
minutes of training performed during the week. The athletes were grouped by
athlete category and event group and finally ranked into quartiles by their
training load score into TLRI categories Q1 to Q4. The stated intensity in the
weekly reports in our study should be regarded as displaying periodization in
training rather than a subjective measure of perceived training-related
exertion.

**Injury severity**

The severity of injury in the context of sports often reflects the impact the
injury has on the athlete’s ability to participate fully in training and/or
competitions (38, 60). We used time loss, in accordance with consensus in
other studies (9, 11), that is, the number of days missed from the date the
athlete reported onset of injury until they reporting having returned to normal
training. Injuries were classified into missed participation, full or restricted: (1)
slight (1–3 days); (2) minor (4–7 days); (3) moderate (8–20 days); and (4) severe
(>21 days). However, in discordance with the consensus, we classified an
injury as severe at 21 days, compared with >28 days. The main reason for this
was that it has been used previously (5, 61). This classification still gives us the
opportunity to compare at 28 days in the future, if desired, because absence
data were collected.
Statistical methods

Data in paper II are presented using descriptive statistics, frequency and relative frequency (%) for all categorical variables. Chi-squared tests were used to test for differences in proportions of athletes between age groups and gender. Each athlete could report injuries to several body regions, but only the first injury reported for each body region was used in the statistical analyses. Comparisons between the prevalence measures were made with regard to body region, diagnostic group, and subgroups of events (i.e. sprint, jump, throw and long-/middle-distance runners). All tests were two-sided and \( p < 0.05 \) was regarded as statistically significant. We used Statistica v9 (Statsoft Inc, Tulsa, OK, USA) for all the statistical analyses.

In papers III and IV, data were presented using descriptive statistics (i.e. mean, median, standard deviation, minimum and maximum) for continuous data and frequency and relative frequency (%) for categorical variables. The relative frequency of injuries was presented together with the corresponding 95% confidence interval. Differences in the proportions of subjects were analysed using the chi-squared test.

The primary end point in study IV was time to injury. Time 0 was set at the first date at which the participating athlete was free of injury. At baseline, 96 of 278 athletes were identified as being injured, and therefore these athletes were censored until the week after they reported being back in normal training after injury. The analysis population consisted of athletes who satisfied all study entry criteria. Athletes were analysed according to the first injury they reported during the study period. Recurrent injuries in the same location and of the same type as a previous injury were not included in the analyses (15, 62). Time to injury was analysed using the Kaplan–Meier method for presenting data descriptively and the log-rank test was used as a univariate test for differences between subgroups with regard to athlete category (gender vs age group), event group, injury history, number of training hours per week, number of training sessions per week, and categories of training load per week. Multivariate regression analysis for time to injury was done using Cox proportional hazards regression. Published studies have reported that the risk of injury is correlated with age, gender and previous injuries. Therefore, we decided to test for interaction between combinations of these factors in the multivariate analyses. Age group and gender were combined in an age-gender factor with 4 categories: youth male (boys), youth female (girls), adult men and adult female. A previous injury was defined as an injury that had occurred during the year prior to the study year such that the athlete was not able to participate for a period exceeding 3 weeks.

All tests were two-sided and \( p < 0.05 \) was regarded as statistically significant. All calculations were done using SPSS version 18 or higher (IBM Inc., USA).
Ethics

The studies included in this thesis follow the WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects (63). Prior to contact with participants, ethical approval was obtained from the Ethical Committee in Linköping in November 2008 (dnr. M-201-08). All data used in this thesis are anonymous. The injury database was managed and analysed without using the participant’s personal identification number.

Each participant was given written information regarding the objectives of the study and what their participation involved. It was made clear that all participation was voluntary and that they could withdraw at any time. Informed written consent was obtained from all participants in the study. For those less than 18 years of age, approval was also obtained from their parents. Informed written consent was also obtained from all participants in the pilot studies.
Results

Requirements for injury surveillance in athletics (paper I)

The requirements analysis showed that, compared with team sports, the characteristic principle for a prospective injury surveillance study in athletics (13, 64) was to identify and evaluate the thin line between functional over-reaching and overtraining leading to overuse injuries (48, 65) (Figure 2).

In athletics, mainly overuse injuries have been reported previously (20, 23–25, 27, 66), which implies that this injury category must be exactly defined. The first requirement was therefore to specify an exact and clinically relevant definition of an athletics injury.

Second, to design epidemiological studies in athletics, it is necessary to consider the variety of sub-disciplines involved and the complexity inherent in the individualistic athletic population. For instance, training schedules can diverge substantially between different individuals within a sub-discipline (26). Therefore, it is important to have exact data on practice and competition schedules.

Definition of athletics injury

Mainly 3 different types of definitions have been used previously in sport injury surveillance: medical attention, time loss and tissue damage (67). A medical attention definition is when the athlete seeks help from a medical professional. The time loss definition refers to the number of days lost from training and/or events for the athlete. In some reports of injury surveillance, a combination of these 2 definitions is used. A less commonly used definition is tissue damage, which requires an objective visible sign, for example, a muscle tear diagnosis verified by magnetic resonance imaging (MRI).

The definition used in our study has its origin in the time loss definition, used previously for athletics by Bennell and Crossley 1996 (28), and is broader to fit an individual sport such as athletics (16). It was based on the following considerations: (a) due to the characteristics of Swedish athletics whereby athletes live in various locations and therefore will handle the weekly reports themselves; (b) field athletics by nature involves various types of training (e.g. interval, strength, technique, etc.) and therefore when athletes are unable (if injured) to perform what was originally scheduled, they make modifications
in their training but still count this as part of their athletics training; (c) all injuries related to athletics incurred both in training and in competition were included (68); and (d) injuries reported in this study were from the athlete’s subjective perspective and experience of musculoskeletal pain and/or soreness.

The chosen athletics injury definition was used in studies III and IV.

**Figure 2.** Associations underlying the study protocol specification (reprinted from Jacobsson J et al. Design of a protocol for large-scale epidemiological studies in individual sports. Br J Sports Med 2010;44:1106–11; with permission).

**Individual-level data collection**

Based on the characteristics of Swedish athletics, a surveillance protocol was designed based on Internet technology, which required the individual athlete to actively take part in the surveillance process. The data were collected from individual athlete using a combination of a web-based injury surveillance
system and a postal survey. Web-based survey methods have been reported to be reliable, in particular among young adults (69, 70).

Study population (papers II, III - IV)

In paper II, 278 athletes (87% of the study population) submitted their assessment via the web survey. During the study year (papers III and IV), 292 athletes (91% of the study population) submitted weekly reports covering 135,031 hours of exposure to athletics. The mean age of the participants in papers II to IV was 24 years (range 18–37 years) for adult athletes and 17 years (range 17–17 years) for youth athletes (Table 6). Analysis of the non-responders could not display any differences between enrolled and non-enrolled subjects with regard to age, gender, event or ranking.

Table 6. Characteristics of the study population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Senior</th>
<th>Youth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (n = 90)</td>
<td>Male (n = 76)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>23.4 (4.6)</td>
<td>24.5 (5.0)</td>
</tr>
<tr>
<td>Height (cm)*</td>
<td>170.6 (6.2)</td>
<td>184.8 (7.1)</td>
</tr>
<tr>
<td>Weight (kg)*</td>
<td>62.6 (12.9)</td>
<td>82.0 (17.1)</td>
</tr>
<tr>
<td>Main event group (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throw</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Sprint</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>Middle/long distance</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Combined events</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Jump</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>Serious injury in previous year (%)**</td>
<td>44</td>
<td>49</td>
</tr>
</tbody>
</table>

*Values missing for 16 athletes (276). **Values missing for 19 athletes (273). ***Mean 52 week. Training volume includes all training, i.e. normal and performed when injured. Values in parentheses are SD.

Prevalence of injuries (paper II)

Injury prevalence

The overall 1-year retrospective injury prevalence was 42.8% (95% CI 36.9–49.0%). Twenty-one athletes reported injuries to 2 body regions and 3 athletes reported injuries to more than 2 body regions. The point prevalence of ongoing injury was 35.4% (95% CI 29.7–41.4%). Fourteen athletes suffered from injuries to 2 body regions at the time of data collection and 2 reported having suffered injuries to more than 2 body regions. Thirty-four athletes reported that they had no injury lasting for more than 3 weeks during the last
12 months, but they were suffering from an injury at the time of data collection.

The 1-year injury prevalence had a tendency to vary with regard to gender and age ($p = 0.11$). The highest 1-year prevalence was found in male senior athletes (50%), followed by female senior athletes (47%), female youth athletes (44%), and male youth athletes (29%). The point prevalence varied with gender and age ($p = 0.025$). The highest point prevalence was found in female youth athletes (45%), followed by female senior athletes (39%), male senior athletes (36%) and male youth athletes (18%). Post hoc comparisons showed that the 1-year prevalence ($p = 0.06$) and point prevalence ($p = 0.025$) of injury were higher among female youth athletes than male youth athletes. There was no gender difference in injury prevalence among the senior athletes.

The diagnostic group that displayed the highest 1-year prevalence (20.9% (95% CI 16.2–22.2%)) and point prevalence (23.2% (95% CI 18.4–28.7%)) of injury was inflammation and pain with gradual onset. A higher 1-year prevalence (16.5% (95% CI 12.2–21.4%)) than point prevalence (8.5% (95% CI 5.5–12.5%)) was recorded for sudden onset injuries in the sprain, strain and rupture group. The body region displaying the highest injury prevalence in both 1-year prevalence and point prevalence was the knee and lower leg (1-year prevalence 15.0% (95% CI 11.0–19.8%; point prevalence 13.7% (95% CI 9.8–18.3%)), followed by the Achilles tendon, ankle, and foot/toe (1-year prevalence 11.7% (8.2–16.1%; point prevalence 11.4% (95% CI 7.9–15.8%)). There was no statistically significant difference between the 1-year retrospective and point measures was observed with regard to the prevalence of injuries to different body regions, nor did the measures differ with regard to injury prevalence in the different event categories. No difference between event categories was verified statistically, but throwing athletes displayed the highest point prevalence (49% (95% CI 35–63%)) and the lowest 1-year prevalence (35% (95% CI 23–49%).

Illnesses reported as a reason for not participating are not included in the reported prevalence measures: 3 athletes (iron deficiency, myocarditis) in the point prevalence and 2 athletes (angina) in the 1-year prevalence (unpublished results).

**Incidence of injuries (papers III, IV)**

**Incidence of injured athletes**

A total of 199 (68%) athletes (adult 122 (73%) and youth 77 (61%)) reported at least one injury during the 52-week study period and the median time to first injury was 101 days (95% CI 75–127). One hundred and twenty-two (42%) athletes reported more than one injury and 70 (24%) athletes reported more
than 2 injuries (Figure 3). There was a statistically significant difference with regard to gender and age in the proportion of athletes who avoided injury ($p = 0.043$); 16 men (21%), 28 women (31%), 20 boys (36%) and 29 girls (41%) girls reported no injury during the study period. Differences between event groups could not be demonstrated statistically ($p=0.937$). Table 7 presents all injuries reported in the event groups. The cumulative injury incidence was 3.57 injuries per 1000 hours of exposure to athletics (men 3.76/1000 h, women 3.62/1000 h, boys 3.89/1000 h and girls 3.13/1000 h).

![Figure 3. Distribution of the number of injuries sustained by the injured athletes and time of the injury events during the study year displayed by injury order (1–9).](image)

**Injury mechanism/circumstances of injuries**

Most injuries (73%) were reported to have occurred during training; 13% from technique-specific training, 12% from interval training, another 12% from sprint training, 11% from warm up, and 10% each from distance running and weight training (information missing for 32% of the training injuries). Eighteen percent of the injuries were reported to have occurred during competitions (information on 9% of injuries was missing). For non-traumatic injuries, the athletes reported having experienced soreness/pain in the affected body part 1–2 weeks preceding the injury event for 53% of injuries with gradual onset, compared with 34% of injuries with sudden onset ($p = 0.001$).
Injury locations, types and rates

A total of 482 injuries were reported (Table 7); 199 (41%) primary injuries and 283 (59%) were recurring (22, 8%) or subsequent (261, 92%) injuries. The lower extremity accounted for 369 injuries (77%), 236 (76%) in adults and 133 (78%) in youths. The most common body location was the Achilles, ankle, foot/toe (136, 28%), hip, groin, thigh (117, 24%) and knee, lower leg (116, 24%). As many as 464 (96%) of all injuries reported were classified as non-traumatic (caused by overuse), 267 (55%) had a gradual onset and 197 (41%) had a sudden onset. Two hundred and forty-six injuries (51%) were of the inflammation and pain type followed by sprain, strain and rupture (190, 39%).

The most frequent diagnosis for all injuries classified according to ICD-9-CM was strains of hip and thigh (68, 14%), followed by Achilles bursitis, tendinitis (65, 14%) and sprained ankle, foot (51, 11%). For adults, the 3 most common diagnoses were Achilles bursitis, tendinitis (54, 17%), sprain, strains of hip and thigh (41, 13%) and injuries in 2 groups, sprained ankle, foot and patellar tendinitis, bursitis (28, 9%). Youth reported most injuries in sprains, strains of hip and thigh (27, 16%), sprained ankle, foot (23, 14%) and shin splints (21, 13%).

In each different subgroup, the most frequently reported diagnosis was hamstring strain (23, 5%) in sprinters, calf/shin (22, 5%) and Achilles tendinitis/bursitis (19, 4%) in middle and long distance runners, lumbago (11, 2%) in throwers; jumpers had mostly thigh injuries with gradual onset (11, 2%) and hamstring strains (10, 2%) (Table 7) (unpublished results).

Injury severity

The severity of injuries is presented in Table 8 and the majority of reported injuries (247, 51%) led to absence from normal training for more than 3 weeks. There were no differences in the severity of injuries with regard to athlete category (p = 0.916). There was a tendency for the severity of injury to increase with the order of injury (1st injury, 2nd injury, etc.) (p = 0.110). Severe injuries were predominantly located in the thigh/groin with a gradual onset (45, 9%), the posterior thigh with a sudden onset (45, 9%), followed by Achilles tendinitis (39, 8%) and calf/shin splints (36, 7%).
Table 7. All injuries (youth + adult): frequency of 1-year prospective time loss injury among athletics athletes by event category (columns) and body region (rows)

<table>
<thead>
<tr>
<th>Body region</th>
<th>Throwing</th>
<th>Sprints</th>
<th>Middle/long distance</th>
<th>Jumping</th>
<th>Combined</th>
<th>Total</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n = 57$</td>
<td>$N = 77$</td>
<td>$N = 83$</td>
<td>$n = 58$</td>
<td>$n = 17$</td>
<td>$n = 292$</td>
<td></td>
</tr>
<tr>
<td>G, gradual onset; S, sudden onset.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VERTEBRAL COLUMN

<table>
<thead>
<tr>
<th></th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head, face</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3 (1)</td>
</tr>
<tr>
<td>Cervical, thoracic</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>5 (1)</td>
</tr>
<tr>
<td>Lumbar, pelvic, sacrum</td>
<td>14</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

EXTREMITIES

<table>
<thead>
<tr>
<th></th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Shoulder</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Upper arm, elbow</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Forearm, wrist, hand</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hip, groin, thigh</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>11</td>
<td>28</td>
<td>0</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Knee, lower leg</td>
<td>12</td>
<td>5</td>
<td>0</td>
<td>20</td>
<td>6</td>
<td>0</td>
<td>43</td>
<td>7</td>
</tr>
<tr>
<td>Achilles tendon, ankle, foot/toe</td>
<td>3</td>
<td>8</td>
<td>1</td>
<td>20</td>
<td>19</td>
<td>0</td>
<td>32</td>
<td>8</td>
</tr>
</tbody>
</table>

UNCLASSIFIED BY SITE

<table>
<thead>
<tr>
<th></th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
<th>Non-traumatic injuries</th>
<th>Traumatic injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtotal</td>
<td>44</td>
<td>43</td>
<td>2</td>
<td>60</td>
<td>62</td>
<td>0</td>
<td>96</td>
<td>30</td>
</tr>
</tbody>
</table>

Number of body regions | 89 (9%)
Number of athletes | 68 (55–80)
Proportion (% (95% CI)) | G, gradual onset; S, sudden onset.
Table 8. Frequency and proportion of athletes with various numbers of injuries (1 to 6 or higher) during the 1-year study period by severity, sex and age (slight and minor injuries are merged into one category)

<table>
<thead>
<tr>
<th>Order of injury</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6 or higher</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td><strong>Male youth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>10</td>
<td>28.6</td>
<td>6</td>
<td>25.0</td>
<td>3</td>
<td>27.3</td>
<td>0</td>
</tr>
<tr>
<td>Moderate</td>
<td>10</td>
<td>28.6</td>
<td>7</td>
<td>29.2</td>
<td>2</td>
<td>18.2</td>
<td>3</td>
</tr>
<tr>
<td>Severe</td>
<td>15</td>
<td>42.9</td>
<td>11</td>
<td>45.8</td>
<td>6</td>
<td>54.5</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>100.0</td>
<td>24</td>
<td>100.0</td>
<td>11</td>
<td>100.0</td>
<td>8</td>
</tr>
<tr>
<td><strong>Male adult</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>16</td>
<td>26.7</td>
<td>11</td>
<td>30.6</td>
<td>4</td>
<td>17.4</td>
<td>2</td>
</tr>
<tr>
<td>Moderate</td>
<td>19</td>
<td>31.7</td>
<td>10</td>
<td>27.8</td>
<td>6</td>
<td>26.1</td>
<td>5</td>
</tr>
<tr>
<td>Severe</td>
<td>25</td>
<td>41.7</td>
<td>15</td>
<td>41.7</td>
<td>13</td>
<td>56.5</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>100.0</td>
<td>36</td>
<td>100.0</td>
<td>23</td>
<td>100.0</td>
<td>16</td>
</tr>
<tr>
<td><strong>Female youth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>11</td>
<td>26.2</td>
<td>2</td>
<td>9.5</td>
<td>3</td>
<td>25.0</td>
<td>0</td>
</tr>
<tr>
<td>Moderate</td>
<td>13</td>
<td>31.0</td>
<td>6</td>
<td>28.6</td>
<td>2</td>
<td>16.7</td>
<td>0</td>
</tr>
<tr>
<td>Severe</td>
<td>18</td>
<td>42.9</td>
<td>13</td>
<td>61.9</td>
<td>7</td>
<td>58.3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>100.0</td>
<td>21</td>
<td>100.0</td>
<td>12</td>
<td>100.0</td>
<td>4</td>
</tr>
<tr>
<td><strong>Female adult</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>16</td>
<td>25.8</td>
<td>6</td>
<td>14.6</td>
<td>4</td>
<td>16.7</td>
<td>4</td>
</tr>
<tr>
<td>Moderate</td>
<td>19</td>
<td>30.6</td>
<td>9</td>
<td>22.0</td>
<td>5</td>
<td>20.8</td>
<td>4</td>
</tr>
<tr>
<td>Severe</td>
<td>27</td>
<td>43.5</td>
<td>26</td>
<td>63.4</td>
<td>15</td>
<td>62.5</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>62</td>
<td>100.0</td>
<td>41</td>
<td>100.0</td>
<td>24</td>
<td>100.0</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>53</td>
<td>26.6</td>
<td>25</td>
<td>20.5</td>
<td>14</td>
<td>20.0</td>
<td>6</td>
</tr>
<tr>
<td>Moderate</td>
<td>61</td>
<td>30.7</td>
<td>32</td>
<td>26.2</td>
<td>15</td>
<td>21.4</td>
<td>12</td>
</tr>
<tr>
<td>Severe</td>
<td>85</td>
<td>42.7</td>
<td>65</td>
<td>53.3</td>
<td>41</td>
<td>58.6</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>100.0</td>
<td>122</td>
<td>100.0</td>
<td>70</td>
<td>100.0</td>
<td>42</td>
</tr>
</tbody>
</table>
Risk factors and risk indicators

The univariate log-rank test showed differences in injury risk with regard to athlete category (female youth, male youth, female adult and male adult; \( p = 0.046 \)), serious injury during previous season (yes/no; \( p = 0.039 \)), and TLRI (index quartiles; \( p = 0.019 \)). No differences among event groups could be demonstrated statistically (\( p = 0.879 \)). The median time to injury was 69 person days (95% CI 31–107) for previously injured athletes and 105 person days (95% CI 59–150) for those with no 3-week injury the previous year. The median time to injury was 227 person days (95% CI 1–453) for athletes in TLRI category Q1 and 98 person days (95% CI 68–128) for those in Q4.

The results of the multivariate Cox regression analyses are presented in Table 9. The results demonstrate a statistically significant interaction effect between athlete category and history of serious injury (\( p < 0.001 \)). Youth male athletes with a severe injury the previous year had more than a fourfold increased risk (hazard ratio (HR) 4.39; 95% CI 2.20–8.77) and adult males had more than a twofold risk (HR 2.56; 95% CI 1.44–4.58) of sustaining a new injury compared with youth females with no previous injury. Athletes in the third (HR 1.79; 95% CI 1.54–2.78) and fourth quartile (HR 1.79; 95% CI 1.16–2.74) had almost a twofold increased risk of injury compared with their peers in the first quartile.

Table 9. Results of Cox proportional hazard multivariate regression analysis for the outcome variable, time to injury

<table>
<thead>
<tr>
<th>Athlete category × previous serious injury</th>
<th>( p ) value</th>
<th>HR</th>
<th>95% CI for Exp (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Youth female × no injury ( ^{a} )</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth female × injury ( ^{b} )</td>
<td>0.351</td>
<td>1.358</td>
<td>0.714</td>
</tr>
<tr>
<td>Youth male × no injury ( ^{a} )</td>
<td>0.464</td>
<td>1.266</td>
<td>0.673</td>
</tr>
<tr>
<td>Youth male × injury ( ^{b} )</td>
<td>0.000</td>
<td>4.389</td>
<td>2.198</td>
</tr>
<tr>
<td>Adult female × no injury ( ^{a} )</td>
<td>0.076</td>
<td>1.665</td>
<td>0.948</td>
</tr>
<tr>
<td>Adult female × injury ( ^{b} )</td>
<td>0.062</td>
<td>1.756</td>
<td>0.973</td>
</tr>
<tr>
<td>Adult male × no injury ( ^{a} )</td>
<td>0.052</td>
<td>1.767</td>
<td>0.996</td>
</tr>
<tr>
<td>Adult male × injury ( ^{b} )</td>
<td>0.001</td>
<td>2.563</td>
<td>1.435</td>
</tr>
</tbody>
</table>

**TLRI**

<table>
<thead>
<tr>
<th>Quartile</th>
<th>( p ) value</th>
<th>HR</th>
<th>95% CI for Exp (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 0–25</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2 26–50</td>
<td>0.147</td>
<td>1.390</td>
<td>0.890</td>
</tr>
<tr>
<td>Q3 51–75</td>
<td>0.009</td>
<td>1.792</td>
<td>1.154</td>
</tr>
<tr>
<td>Q4 76–100</td>
<td>0.008</td>
<td>1.787</td>
<td>1.165</td>
</tr>
</tbody>
</table>

The analyses included factors that were associated with statistical significance to the outcome variable in the univariate tests and relevant interactions between these factors.

\( ^{a} \)No severe injury reported in the 12 months prior to the study. \( ^{b} \)Severe injury reported during the 12 months prior to the start of the study.
General discussion

In this thesis, a protocol for epidemiological injury surveillance in athletics was developed (paper I) and implemented in 2 cohorts of elite athletics. To maintain compatibility with the consensus statement reported for team sports, the aim was that as many features as possible from existing guidelines be transferred to the athletics protocol (paper I).

Both prevalence measures (paper II) and the incidence (paper III) revealed a heavy burden of musculoskeletal injuries in elite athletics athletes; close to 8 out of 10 recorded injuries affected the lower extremities. Moreover, about every second injury reported was found to be severe. Most of the recorded injuries were non-traumatic with gradual onset, indicating overuse. Regarding risk factors, the principal findings (paper IV) were that a severe injury the previous season and a high relative training load index score predicted the risk for a new injury during the study year.

Generalizability of findings

Study population and representativeness

In general health studies, an important dimension and well-recognized problem is how well the sample in a study represents the target population (71). Hard-to-reach populations are defined according to the characteristics of the setting (e.g. cultural, behavioural, structural) and demographics (72) where a sporting population like ours has points of contact in all fields (paper I). This is a concern for the interpretation of the results obtained in a study; that is, can the results be generalized over the entire population and do they support future interventions? Some important issues in this current study that need to be acknowledged are: whether all those defined as being elite athletes were reached and whether the final sample size was large enough to be representative. Paper I describes the efforts made to overcome the obstacles in reaching this specific population by developing a protocol for epidemiological studies in an individual sport.

This study aimed to examine the occurrence of injuries in elite athletes, defined as being in the top 10 list in any one discipline. The criterion was chosen in an effort to reach athletes most likely sharing similar objectives regarding training but also presumably personal ambitions to achieve success in competition. However, one potential limitation of this study was that the selection of entrants to participate was on a voluntary basis which could lead
to a risk for participation bias. One cause for participation bias is that elite athletes affected by season-long injuries the preceding season were not included in the top 10 Swedish ranking lists and therefore were not invited to participate in the study, which might have led to selection bias. This non-healthy worker effect (73) may have biased the study population towards including more healthy athletes. This could be regarded more as a confounding factor than a selection bias (74). Moreover, participation in longitudinal studies that rely on self-reports depends on the individual athlete’s interest and requires a great deal of personal commitment (i.e. 52 weekly submissions during the study year), in contrast with team sports where data are commonly collected by a staff member.

The recruitment of athletes, young as well as adult, turned out to be more time consuming than expected, because no licensing system or central address register exists for those participating in the sport. The majority of addresses for the adult athletes were obtained from the Swedish Athletics (SAA), which does keep records for those that have taken part in activities organized by the federation, however about 20% of these envelopes were returned to sender and current addresses had to be sought from clubs and on the Internet. Younger athletes tended to belong to smaller local clubs in cities close to their home and none of the entrants in the youth cohort were identified from the lists provided by the SAA. Addresses for this group were requested from the clubs and Internet searches. There is a high likelihood that both youth and adult athletes move around for different reasons, for example, entering a new school. This observation illustrates another area of concern, namely the group of non-responders and we cannot rule out that some never received an invitation in the first place. This highlights one issue that may partly explain the limited number of studies performed in individual sports in contrast to team sports. In some countries, such as the United States, athletics for youths is mainly delivered in school settings (high school and college) and this could facilitate targeting athletes for study purposes (35). For the SAA and in comparable settings, this is one area that needs to be addressed to facilitate similar data collections in the future.

Since the study population was defined as those among the top 10 in Sweden at the end of the 2008 season and because this was a total population study, no power calculations were performed before the data collection. Almost 50% of the targeted population finally consented to participate in this 1-year individual-level study, which can be considered satisfactory. The analysis of the non-responders did not reveal any differences regarding the groups (with regard to age, gender, subgroup and ranking), suggesting that the sample was representative of the Swedish elite athletics athlete population. However, before our results can be adopted, the context in which athletics is delivered in other athletics settings needs to be considered because differences in relation to our study could affect, for example, the implementation process of intervention programs.
Data collection

E-epidemiology refers to the science of applying epidemiological knowledge using digital media, for example, the Internet, for data collection and has been found feasible in large-scale epidemiological studies (69). Paper I describes the process of designing a weekly e-diary distributed via the Internet and the efforts made to develop it to take as little time as possible to fill in. A high response rate was shown in paper III, with more than 90% of entrants submitting weekly reports, suggesting this is a feasible way of collecting data in these populations. Individual athletes do, in general, take greater responsibility for their own training compared with, for example, team athletes and the goals of the sport are highly personal to the individual. However, some considerations need to be addressed for future studies in similar groups of elite athletes. First, elite athletes might have other obligations such as filling in anti-doping notifications, so-called whereabouts. If athletes are faced with additional demands such as weekly reports, their willingness to participate might decline, highlighting that the design of the web documents is vital. Second, it is important that the participant’s confidentiality and privacy is not jeopardized and the security of the web programs used must not be compromised (75). These 2 factors may affect the athletes’ interest in participating and may thus have an impact on the response rate in a study. Moreover, if the response rate in a study is low, this could influence the precision of the results (76).

Injury definition and categorization

Injury definitions

Differences between studies regarding the design, definitions and settings are reflected in the rate and incidence of injuries in athletes and emphasize the importance of overall uniformity in how data are collected and reported in athletics. Reportable injuries in the present study follow earlier consensus statements (9,10), in which time loss definitions are recommended, and they encompass injuries occurring at both training and competition. The data are prospectively collected via self-reports and reflect the individual athletes interpretation of the definition of injury that they received. The definition of injury used and to what extent proposed definitions actually exclude injuries has been acknowledged as a problem by several authors (16, 68, 77).

Overuse injuries have various causes (78) and little knowledge exists about the incidence and associated risk factors with these types of injury because there is a lack of epidemiology in this area in sports (79). It has been suggested that existing injury definitions, used primarily in team sports, do not identify
overuse injuries because their onset is usually insidious rather than due to a definite event (77, 79).

Injuries linked to overuse have been described as being one of the most frequent reasons, exceeding 70%, for visiting a sports medicine clinic (80) and the challenge with the methodology of how to capture these conditions has been discussed (81). These injury types have drawn little attention when it comes to preventative interventions (82) even though such efforts have had efficacious long-lasting effects in well-targeted groups of athletes (83).

The requirements analysis conducted in paper I indicated that a central requirement for the protocol was to allow for detailed epidemiological analyses of overuse injuries. These conclusions had several consequences for the detailed design of the protocol. First, the self-reported injury events had to be defined broadly enough to cover conditions resulting from loads at the borderline between over-reaching and overuse but be sufficiently exact to allow rigorous recording of events that could be considered medically, by coaches, and from the perception of individual athletes to be an injury.

The injury definition used in papers III and IV is broad in the sense that it captures injury events reported both in training and competition, and includes restricted participation defined as partial time loss, that is, not fully participating in normal scheduled athletics activities (Figure 3). It could be argued that this could lead to too much information being collected and some events reported might not be injuries from a medical perspective with a distinct pathology and clear tissue damage. However, most of the injuries accounted for in this study were severe, causing more than 3 weeks loss of full

Figure 3. How are overuse related events captured?
participation in athletics. From the viewpoint of the elite athlete, injuries associated with only minor tissue damage (e.g. overuse injuries) might have a substantial negative impact on personal achievements (12). Almost every second athlete with a gradual onset of injury reported having felt “something” in the affected body area 1–2 weeks prior to injury onset suggesting that pain/soreness might be a proxy to target this specific type of overuse-related condition (81). This finding emphasizes the need to collect data from the individual athlete to support planning of preventative programs (84)

**Categorization of injuries**

An important issue in sports injury epidemiology is the lack of a uniform coding system identifying related injuries and there has been discussion on how to standardize the collection of information (12, 85–87). In papers II and III, a matrix that was initially developed by Barell et al (58) for categorization of traumatic injuries and further developed by Hauret et al (57) to allow for inclusion of musculoskeletal injuries related to microtrauma, was adjusted to fit athletics. Our matrix for athletics injuries presents the nature (type) of injury in diagnostic groups in the columns and the injured body regions in the rows. The columns display injuries with a non-traumatic origin, presenting either gradually or with sudden onset, and traumatic injuries. The categorization of the diagnoses as ICD-9-CM codes and placement in their appropriate cells gives substance to the matrix.

In general clinical practice, the diagnosis of injury is made by physicians. However, many studies in sports medicine rely on data reported by physiotherapists, athletic trainers, etc. The origin of the data in this study was the athletes’ self-reports and not clinical examinations, and all reported injuries were included for classification. Two physicians and one physiotherapist with significant experience in sports medicine categorized the injuries that are the basis for analysis, via information provided by the athletes in the injury report form. A concern with self-reporting is the reliability and the validity of the diagnosis of injuries (88, 89). The injury follow-up questionnaire included a question on whether a medical practitioner had confirmed the diagnosis by a clinical investigation. The injuries recorded were mainly of the overuse type, and affected body areas in accordance with earlier reports from athletics, e.g. back of the thigh, knee and ankle. However, the information provided may well express the athlete’s own opinion regarding the reported injury.

The majority of injuries in papers II and III were categorized as being non-traumatic and the results are assumed to be epidemiologically valid at the level of injury type and body region. This puts further stress on the importance of a uniform classification system because the lack of reported injuries related to overuse in other contexts could partly be explained by this; it is not uncommon that traumatic and acute are used interchangeably (90).
Two injury types that might present with sudden/acute onset are hamstring strains and stress fractures although the underlying cause is often described as being associated with cumulative applied stress.

The matrix analysis indicates 2 areas of concern for further use in sports medicine: inflammation/pain and sprains/strains/ruptures since ICD-9-CM codes do not fully capture overuse injuries and therefore do not provide sufficient information on the sites and injury types. Future studies should focus on how to methodically analyse these gradual onset injuries in order to enhance the establishment of a proper clinical diagnosis because well-targeted safety protocols are formulated based on the findings captured in the surveillance (46, 91). In addition, as noted by Finch and Boufous (92), it is also necessary to further develop the internationally used ICD coding system to enable identification of injuries related to sports and physical activities, traumatic as well as those related to overuse.

Extent of the problem

Prevalence

The prevalence measure is used to express the burden, or magnitude, of disease at a particular point in time and the information obtained can provide valuable information for planning interventions activities (74). However, prevalence is not useful for determining what caused the disease.

Both prevalence measures used in paper II revealed a heavy burden of musculoskeletal injuries in elite track and field athletes; the 1-year prevalence of injury lasting for more than 3 weeks in the preceding year was 43% (95% CI 37–49%), whereas the point injury prevalence was 35% (95% CI 30–41%). The point prevalence measure accounted for fewer injuries in the sudden onset sprain/strain/rupture diagnostic group than the 1-year measure. This observation may reflect that these injuries are caused by acute overload, commonly associated with invoking close to maximal muscular strength in competitive situations. Seasonal variations in competition and practice schedules can therefore affect measures of point injury prevalence in athletics. Our cross-sectional data collection in paper II was conducted immediately after the indoor season in Sweden and when general preparation for the outdoor season had started. When using point prevalence as a measure of injury burden in athletics, when to conduct a survey during a season should be considered carefully because this is likely to influence the outcome.

When interpreting the results in paper II, the validity of the self-reported 1-year history of injury may be influenced by recall bias. Junge et al (13) compared prospective data collection by physicians with retrospective data collected from players and found a significantly lower incidence of injury in
the retrospective material. In studies covering both individual and team sports, prospective registrations by medical staff were also compared with retrospective interviews with the athletes (93, 94) but these studies presented an underestimate of the injury burden in the data recorded by the medical staff. Florenes et al. (93) actually captured more injuries by retrospective self-reports. In addition, in the setting of Australian football players, Gabbe et al (64) reported good accuracy for 12 months recall of being injured or not and the body region affected but less accuracy regarding injury diagnosis. These slightly conflicting results suggest that recall bias might be multi-levelled and that the validity, especially regarding detailed information such as the diagnosis, should be interpreted with care.

**Incidence**

Incidence is a measure of disease occurrence in populations based on prospective data collection and can be used to help determine causality (74). In this thesis, new cases of musculoskeletal injuries were recorded.

Few studies in athletics have prospectively followed athletes representing all events during an entire season. The annual athlete-level injury incidence of 68% in this study is similar to what has been described previously in more specific athletics populations (25, 27, 28). There was no difference in the annual incidence between subgroups of events similar to the study reported by Bennell and Crossley (28). The injury incidence rate (3.57 injuries per 1000 hours of exposure) is in line with the results of Lysholm and Wiklander (27) and Bennell and Crossley (28). How these findings in Sweden compare with those in other countries is unknown because current figures are not available in similar populations. Girls were most likely to evade injuries, which is in accordance with findings from a recent review (95). However, this raises an area of concern when youth athletes report close to the same incidence as adult athletes, because the substantial risk for incurring additional injuries is established in sport settings. A limitation in paper III is the notion of new injury. The results suggest that it may not have been the athlete’s factual first injury that was recorded as the first injury during the study period, but rather one in a sequence of inter-connected injuries. This indicates that more investigations on recurrent injuries and the lifetime prevalence of injuries in athletics are warranted.

The majority of injuries reported in paper III were from athletics training. One explanation for this finding could be that athletics competition demands that the athlete is close to 100% fit. Therefore, athletes with vague symptoms may have chosen to replace competition with training and may have sustained the threatening injury during training instead.
Reported injury types

This study followed athletes competing in all disciplines in athletics. In accordance with earlier studies, most reported injuries (close to 8 out of 10 recorded) affected the lower extremities, 76% for the 1-year prevalence (paper II) and 77% for prospective registration (paper III) (20, 21, 23, 24, 27, 28). The vertebral column region accounted for 13% of injuries in paper II and 16% in paper III. Only 4% of the reported injuries in paper III were classified as traumatic, which is consistent with previous studies in athletics (20, 27, 28, 96). This study showed similar patterns for both adults and youths.

The most frequently reported diagnosis in paper III was strains/cramps of hip/thigh. The exact location and nature of these injuries was not determined because MRI reports were not obtained. Muscle injuries, especially hamstring strains, are a common diagnosis (14%) reported from competitions (20–22), and a 12-month study showed a 14% incidence of hamstring strain (28). Our findings raise concerns about identification of risk factors for prevention due to the high risk for re-injuries (97, 98). Another area with a high number of reported injuries was the Achilles. This is in accordance with observations described earlier in runners (99).

Stress fractures are commonly associated with athletics. Bennell et al (66) reported a 21% incidence in their cohort; only 4% of stress fractures confirmed by MRI were identified in our study. However, overuse injuries are generally clinically diagnosed and a stress fracture can remain undiagnosed for several weeks if the athlete undergoes further investigations only when symptoms persist (100). This implies that this specific type of diagnosis may have been under-reported in our study.

Factors associated with risk for injury

The findings in this thesis suggest that there likely are gaps in sports epidemiology, in this case regarding the incidence and risk factors associated with overuse injuries, because almost all the injuries identified in this study were of the non-traumatic type (79). Moreover, overuse injuries have drawn little attention when it comes to preventative interventions (82). In a recent study, van Wilgen et al (101) interviewed athletes and coaches about their perceptions on what constitutes the onset of an overuse injury and physical, psychological as well as social factors, were regarded as being related. This illustrates that the underlying cause is complex and emphasizes the importance of exploring possible synergies between the extrinsic and intrinsic risk factors usually investigated in sports (102).

In studies covering athletics, there have been conflicting results on how incidence rates have differed by gender (21, 25, 28) and there is little
agreement also in other sports (103). The 1-year retrospective prevalence in paper II showed a tendency to vary with regard to gender and age; the highest retrospective prevalence was found in male adults, whereas the point prevalence was highest amongst female youth. Furthermore, in papers III and IV, it was found that male adult athletes had the highest injury risk, similar to what has been observed in adult elite athletics competitions (21), and female youth athletes had the lowest injury risk. Moreover, in agreement with Bennell and Crossley (28), we found no association between subgroups of events with regard to injury risk. This suggests some systemic effects from athletics training (e.g. during the pre-season close to the first competitions) and requires further study. In a retrospective analysis, D’Souza (25) found that most injuries occurred at the beginning of the season and similar results were observed by Rauh et al (104) in a longitudinal study of cross-country runners.

Paper IV showed that a severe injury (>3 weeks) the preceding year was associated with a risk for a new injury during the study period. Further analysis showed that the risk for male youth athletes was close to 4 times higher than female youth athletes free of previous injury. Because there is not much epidemiological knowledge about youth elite athletes available in the literature, limited information is available about the possible impact of previous injuries (105). To understand and further develop preventative safety programs, insight into athletes’ perceptions of injury risks is essential (106), and the literature suggests that these perceptions may be gender specific (107).

Injury profiles are known to differ between sports (108) and certain sports have reported patterns of injuries linked to overuse that are also site specific, for example, climbers with tendinopathies located in the hands and fingers (109). These sports are characterized by recurrent discipline-specific movements and loads suggesting a connection with working routines, similar to settings describing work-related overuse injuries (110, 111). An association between a high throwing work load and a risk for upper limb injuries has been reported in elite cricketers (112). In addition, in a general population of adolescents, Auvinen et al (113) observed that the prevalence of musculoskeletal pain was higher for those participating in one single sport compared with those who were active in several sports.

At the elite level, athletics training during the preparation period consists of periods of weight training, sprinting, endurance, discipline-specific training, jumping, etc. all performed at a high level with relatively long training sessions and with increasing intensity, especially closer to the competition season. However, not much research has been done linking injury profiles to training-related factors, which can be explained in part by the fact that quantifying training loads is a challenging task (114). Similar to Bennell and Crossley (28), we could not confirm any association between injury rates and hours or sessions trained, even though our results showed a tendency to increased injury risk when sessions per week increased in number.
However, we noted a significant association between injury and relative training load measured as a combination of hours and intensity. A similar relationship between the intensity in practice and the incidence of overuse injury has been noted previously in elite settings (115–118). However, these reports were not available at the time of this study was designed and our TLRI should be considered as an explorative attempt to further quantify training load. The intensity stated in the weekly reports in our study displays the planned periodization in training, rather than being a subjective measure of perceived training-related exertion. In the study by Bennell and Crossley (28), the injured athletes attributed close to 80% of injury occurrence, particular of the overuse type, to a change in training during the month preceding injury; the most frequent cause was an increase in training intensity. In rugby, Gabbett (119) also demonstrated a correlation between reduction in pre-season training loads and fewer reported injuries. The dose–response relationship, or in sports rather the training–performance relationship (119), highlights an important area for further research because optimizing training without any adverse effects such as injuries is highly warranted in any elite sports setting.

Several considerations have to be taken into account when drawing conclusions from paper IV. The aim was to reach the entire population of elite athletic athletes in Sweden. Therefore, no power calculation was performed to establish the size of the study population or as a basis for statistical testing. An evident risk for type 2 errors must thus be accounted for when interpreting the results, in particular at the subgroup level. Also, the non-participation in the study in relation to the primarily invited population was relatively low (less than 50%). However, the drop-out was not found to be skewed with regard to age, sex, event group, and ranking. Both these facts need to be taken into regard when interpreting the results. Furthermore, no anthropometrics data were included implying that some explanatory variables causing injuries might not have been detected. However, not many studies have reported an association between injury outcome and anthropometrics. To improve power in future studies, efforts should be made towards reaching more athletes in the targeted cohorts.

**Consequences of injury**

**Previous and subsequent injuries**

Clinical epidemiological studies in sports, especially at the elite level, are usually designed to follow athletes for one season, one year, etc. and longitudinal reports have mainly been reported from high school settings and team sports (35). One limitation is the notion of a new injury investigated in papers III and IV. The results suggest that it might not be the athlete’s factual first injury that was recorded during the study period, but rather one in a series of interconnected injuries. Having had a previous injury is a commonly
observed risk factor for obtaining a new injury in sports (102, 120–122). Previously in athletics, Bennell and Crossley (28) found that close to 33% of all injuries in athletics were recurrent.

The importance of a clear specification and categorization of subsequent injuries, separating them from recurrence injuries, has recently been emphasized (123, 124). In paper III, we found that successive injuries (subsequent and recurrent injuries) accounted for 59% of all injury events recorded. The low proportion of recurrent injuries found in this study (8% of the successive injuries) can be explained by the strict definitions used. In injury surveillance covering high school team sports and cross-country runners, Rauh et al (103, 125) found that close to 25% of athletes reported multiple injuries defined as subsequent. Why some athletes seem more prone to sustain numerous injuries has not been established. Suggested causes are that some athletes are more frequently exposed to sports or that they not have been adequately rehabilitated from a previous injury. Our findings also highlight, as indicated by Meeuwisse et al. (126), that even though the athletic athlete reports being injured, they might continue participating (partially) and thereby remain exposed to certain risk factors. What the high successive injury rate reported in our study can be attributed to remains unanswered. This observation emphasizes the need for further investigation to identify athletes at increased risk for sustaining multiple injuries, and to examine the consequences of these injuries and consider how these events affect overall athletics performance.

How a previous injury is related to a subsequent injury has not been carefully examined and explanations generally tend to be attributed to intrinsic risk factors, for example, proprioceptive deficits due to inadequate rehabilitation. However, little knowledge exists about the pathway between injury and a subsequent injury, leading to either no treatment and/or inadequate rehabilitation. A number of extrinsic factors may also contribute to why an athlete receives clinical treatment that is not optimal. For example, the athlete may live in an area where there is limited access to clinical professionals specialized in sports medicine, such as physicians and physiotherapists, leading to lack of proper services for diagnosis and rehabilitation. Furthermore, sports medicine practitioners may recommend return to athletics training and competition based on experience from popular team sports, such as football /soccer, that do not train as much as athletes in athletics. In addition, if the coach and athlete underestimate the severity of the injury (99), decisions regarding the need for treatment and return to sport may become systematically biased. Moreover, it has been observed that high-level athletes modify their training while injured but still train at high volume and eventually may even increase loads (116, 117). However, a high number of subsequent injuries were reported in papers III and previous injury was identified as a major risk factor in athletics in paper IV. Therefore, the need to fully understand and identify current gaps and barriers to obtaining adequate rehabilitation for overuse injuries seems to be a most urgent issue (127). These results indicate that further investigations on multiple injuries and the lifetime
prevalence of injuries in athletics are warranted and longitudinal studies are imperative.

**Injury severity**

Paper III showed that both adult and youth elite athletics athletes are at high risk for sustaining not only one injury but also multiple injuries during one season. Every second of the injuries reported were identified as being severe; only 9% were slight injuries (1 – 3 days), implying that the athletes’ reporting threshold (128) was when their performance was clearly limited. A limitation is that the subsequent injuries cannot be assumed to be statistically independent, which needs to be taken into regard when interpreting the results from the analysis of associations between injury order and injury severity. Combining these findings, that is, the risk for additional injury and the severity of injury indicates that the effect that reported injuries have on training and performance in athletics is significant.
Future perspectives

In many countries, such as Sweden, the majority of sports injuries are handled by the general health care system, and not by physicians associated with the national federation of sports associations. Injuries associated with sports activities should therefore not be seen as a matter only for the sport’s governing body. It should also be regarded as a concern for society as a whole, especially since participation in sports is promoted to achieve good health (129), in particular for children and adolescents (105, 130–132).

The knowledge resulting from paper I describing the setting and the specific conditions in which the activities of Swedish Athletics are conducted, provides valuable information that can be used in the future implementation and dissemination of targeted sports safety programs. Understanding of the situation of the key end users (i.e. athletes and their coaches) is essential in the move towards sports safety in Swedish Athletics (133). Also, paper I describes the development of a weekly e-diary that was found to be feasible in this population. This weekly e-diary can be further developed and introduced as routine for longitudinal collection of data on exposure and injury. In addition, to visualize another end-user perspective, representatives from the federation participated in the process of designing the study protocol, contributing with special knowledge on the context.

In paper II, information regarding the extent of the problem with musculoskeletal injuries is provided and thus can serve as a basis for decision makers, that is, key stakeholders in the federation, clubs, etc., on how to allocate future resources (primary prevention) (134). Moreover, the findings of a high injury prevalence among youth athletes in particular also falls within the scope of primary prevention, that is, minimizing the overall occurrence of injuries. Issues to be considered include: Are our youth athletes fit enough to cope with the training offered? How complete is the understanding of mechanisms that lead to overload? How much load can the tissue absorb during training?

Paper III revealed patterns that are incompatible with success in sports, that is, athletes who are injured over and over again, and with injuries affecting training negatively for long periods of time. These findings highlight the urgent questions that need to be answered: why athletes and coaches seemingly do not recognize the early signs of overload (secondary prevention) or why athletes do not receive proper post injury care (tertiary prevention)? Although causal evidence cannot be deduced, the results in paper II and III together with previous reports provides reasons to hypothesize the existence of some type of systematic error in the sport because the different subgroups of events display similar prevalence measures and injury incidence (primary prevention).
The broad definition of athletics injury introduced in paper I and used in paper III showed that the majority of reported injuries were non-traumatic with gradual onset, indicating overuse. Combining the observations made in paper III with the results from the risk factor analysis in paper IV, where 2 particular areas of concern were identified (i.e. a relationship with training load and previously injured athletes), emphasizes that action is needed at all levels of prevention. Further knowledge of the training–performance relationship (cf. dose–response relationship) needs special attention (primary and secondary prevention) and to ensure a safe return to athletics after injury, guidelines and protocols for rehabilitation of specific types of athletics injury (tertiary prevention) need to be developed (135, 136).

Primary prevention is generally attributed to the organization level, its policies and measures, with an aim to reach the entire organization, whereas secondary and tertiary preventions are aimed at the individual and their performance (137). This suggests that involvement of the federation and clubs is essential at the early stages in order to put research findings into practice because they have the means to implement, adopt, disseminate and in a systematic way evaluate the sports safety interventions suggested (138). Future research will involve collaboration between researchers (i.e. content experts), sport medicine professionals, policy makers (i.e. process experts) and representatives from various areas in the real world of athletics (i.e. context experts) (139).

In conclusion, this thesis has examined the health of elite adult and talented youth athletes in Swedish Athletics using clinical epidemiology and presented results to support the first steps towards prevention of injuries related to the sport (43, 140).
Conclusions

• A requirement analysis showed that a central requirement of an injury surveillance protocol for elite athletics should allow for detailed epidemiological analyses of overuse injuries, requiring self-reported data from athletes.

• Both prevalence measures, 1-year retrospective and point, revealed a high prevalence of musculoskeletal injuries in elite athletes.

• The cumulative injury incidence was 3.57 injuries per 1000 hours of exposure to athletics. Differences between event groups could not be demonstrated. Girls were most likely to avoid a new injury during the study year.

• Ninety-six percent of the reported injuries were non-traumatic. Every second injury was severe, causing a period of absence from normal training exceeding 3 weeks.

• Seven out of 10 injuries occurred in the lower extremities; the most common locations were the Achilles tendon and foot, followed by the hip and thigh.

• Previous injury was identified as a risk factor for injury; male youth with a previous injury had more than a fourfold increased risk of injury compared with female youth without previous injury.

• A high training load score was found to be a predictor for a new injury during the study year.
Syftet med avhandling var att beskriva utformningen av ett protokoll för prospektiv klinisk epidemiologisk studie av skador bland friidrottare, studera ett års prevalens, punkt prevalens och incidens av skador i totala kohorter av svensk vuxen elit och talangfulla friidrotts ungdomar; att identifiera riskindikatorer och faktorer för olika skadetyper / mönster i friidrott.

I delarbete I, användes en argument-baserad metod för undersökning av komplexa designproblem till att strukturera insamling och analys av data. Kravanalysen visade att den centrala efterfrågan på protokollet var att möjliggöra för detaljerade epidemiologiska analyser av överbelastnings skador, vilket kräver regelbunden insamling av självrporterad data från idrottaren. Det framtagna studie protokollet centrerades på en webb-baserad elektronisk veckodagbok som möjliggör kontinuerlig insamling av individuella uppgifter om exponering och skador.

I delarbete II, undersöktes prevalensen av skador och 278 idrottare (87%) av studiepopulationen svarade på webbenkäten. Den totala retrospektiva 1-års skade prevalensen var 42,8% (95% konfidensintervall 36,9-49,0%). Punkt prevalensen var 35,4% (95% konfidensintervall 29,7-41,4%). Den 1-åriga skade prevalensen visade en tendens att variera med avseende på kön och ålder (p = 0,11). Den diagnos grupp som uppvisade högst 1-årsprevalens (20,9% (95% Cl 16,2-22,2%)) och punkt prevalens (23,2% (95% Cl 18,4-28,7%)) var skador med inflammation och smärta, med gradvis insättande.

I delarbete III, under 52-veckors studien, lämnade 292 idrottare (91% av studiepopulationen) veckovisa rapporter och rapporterade en kumulativ skade incidens av 3,57 skador per 1000 timmars exponering för friidrott. De flesta skador (73%) rapporterades från träningen. Det var en statistiskt signifikant skillnad med avseende på kön och ålder i andelen idrottare som undvek skada (P = 0,043). Skillnader mellan grengрупп kunde inte statistiskt visas (P = 0,937). Nittiosex procent av de rapporterade skadorna var icke-traumatisk (i samband med överanvändning). Varannan skada var allvarlig, vilket orsakade en period av frånvaro från normal träning överstigande 3 veckor. Sjuttiosju procent av skadorna inträffade i de nedre extremiteterna.

I delarbete IV, rapporterade 199 (68%) av idrottarna en skada under studieåret. Mediantiden till första skadan var 101 dagar (95% konfidensintervall (CI) 75-127). Univariata log-rank test avslöjade skillnad i risk gällande idrott kategori (P = 0,046), allvarlig skada (> 3 veckor) under föregående säsong (P = 0,039) och tränings belastnings rank index (TLRI) (P = 0,019). Idrottare i den tredje och fjärde TLRI kvartilen hade nästan en tvåfaldig ökad risk för skada jämfört med det första kvartilen. Unga män med en tidigare allvarlig skada hade mer än en fyrdubbel risk för skada jämfört med unga kvinnor utan tidigare skada.
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Stockholm, August 2012
Jenny Jacobsson
Bazinga!!
References


72. Crosby RA, Salazar LF, DiClemente RJ, Lang DL. Balancing rigor against the inherent limitations of investigating hard-to-reach


Appendix 1

LINKS TO WEB DOCUMENTS;

MASTER Baseline SWE  
http://entest.internetborder.se/4.5f13b5361230899f917800017558.html

MASTER Baseline ENG  
http://entest.internetborder.se/4.5f13b5361230899f917800018090.html

MASTER Elektronisk veckodagbok SWE  
http://entest.internetborder.se/4.5f13b5361230899f917800017285.html

MASTER E-weekly athlete diary ENG  
http://entest.internetborder.se/4.5f13b5361230899f917800018002.html

MASTER Skadeanmälan SWE  
http://entest.internetborder.se/4.5f13b5361230899f917800017818.html

MASTER Injury report form ENG  
http://entest.internetborder.se/4.5f13b5361230899f917800018349.html

MASTER Slutrapport SWE  
http://entest.internetborder.se/4.5f13b5361230899f917800017714.html

MASTER Injury closure ENG  
http://entest.internetborder.se/4.5f13b5361230899f917800018246.html