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INJURIES, RISK FACTORS, CONSEQUENCES AND INJURY PERCEPTIONS IN ADOLESCENT ELITE ATHLETES

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INJURIES, RISK FACTORS, CONSEQUENCES AND INJURY PERCEPTIONS IN ADOLESCENT ELITE ATHLETES
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ABSTRACT

Background: Injury and health data are not fully explored in adolescent elite athletes, yet essential for understanding injury risk, consequences of injuries and developing injury preventive programs.

Aims: To explore injury patterns, training and health variables, such as nutritional behaviour, self-esteem, self-perceived stress, sleeping habits, as well as identify risk factors for sustaining a sport injury among adolescent elite athletes. Further, to explore consequences of sport injuries and athletes' perceptions and experience of being injured.

Methods: A valid and reliable questionnaire about training exposure, injury and illness was repeatedly e-mailed over one or two years to 680 adolescent elite athletes from 16 different sports at 24 National Sports High Schools. At the start of each term, athletes were sent a background questionnaire about competence-based self-esteem, nutrition, self-perceived stress and sleep. Twenty athletes from the same cohort were interviewed in focus group discussion format about their injury experience and perceptions.

Results: The average injury prevalence and substantial injury prevalence were in year one 31% and 15% and in year two 39% and 18%, respectively. During year two, 30% of the athletes were injured more than half of all reporting times and 10% reported substantial injury more than half of all reporting times. The recommended intake of fruits, vegetables, and fish was not met for 20%, 39%, and 43% of the adolescent elite athletes, respectively. The recommended amount of sleep during weekdays was not obtained by 19%. Increasing the training load, training intensity, and at the same time decreasing the sleep volume resulted in a higher risk for injury compared to no change in these variables. An athlete having the previously mentioned risk factors, with an average competence-based self-esteem score, had more than a threefold increased risk for injury, compared to an athlete with a low perceived competence-based self-esteem and no change in sleep or training volume. The adolescent elite athletes who were interviewed experienced a loss of identity and described a sense of feeling lonely and excluded from regular sports involvements while dealing with the injury. Discrepancies in rehabilitation expectations between athletes and practitioners were expressed, where some athletes described that their rehabilitation was not adjusted to their needs and requested to receive an injury diagnosis in an early stage following injury.

Conclusion: A considerable number of adolescent elite athletes are injured regularly, resulting in serious consequences on sports participation and performance. Sports involvement seems to constitute an important social component for an adolescent elite athlete, and being injured may lead to a loss of identity and experience of loneliness, self-blame or self-criticism. Medical teams, accessible to all athletes at each National Sports High School, are warranted to reduce the unhealthy behaviour, injury risk and help athletes return to sports safely following injury. These medical teams should be aware of the multiple consequences of injury in adolescent elite athletes.

SAMMANFATTNING

Bakgrund: Skade- och hälsodata är begränsat studerat för elitidrottande ungdomar, men nödvändiga för att förstå skaderisk, skadors konsekvenser och för att utveckla skadeförebyggande åtgärder.

Syfte: Att undersöka skademönster, träning och hälsovariabler som kost, självkänsla, självupplevd stress, sömnvanor och att identifiera riskfaktorer för skada, hos elitidrottande ungdomar. Vidare var syftet att undersöka skadors konsekvenser och idrottarnas uppfattningar och erfarenhet av att vara skadad.

Metod: Ett valitt och reliabelt frågeformulär om träningsexponering, skadedata och sjukdom skickades ut under ett eller två års tid till 680 elitidrottande ungdomar från 16 olika sporter och 24 nationella Riksidrottsgymnasium. I början av varje termin fick idrottarna fylla i ett bakgrundsformulär om prestationsbaserad självkänsla, kost, självupplevd stress och sömnvanor. Tjugo idrottare från samma kohort intervjuades i fokusgrupper om deras uppfattningar och erfarenhet av att vara skadad.

Resultat: Den genomsnittliga prevalensen av skador och allvarliga skador var under det första året 31 % och 15 % samt 39 % och 18 % under år två. Under år två rapporterade 30 % av idrottarna vara skadade mer än hälften av alla rapporteringstider och 10 % rapporterade allvarlig skada mer än hälften av alla rapporteringstillfällen. Det rekommenderade intaget av frukt, grönsaker och fisk uppnåddes inte av 20 %, 39 % och 43 % av ungdomarna. Totalt nådde inte 19 % av ungdomarna sömnrekommendationen. Att öka träningstiden, intensiteten och samtidigt minska sömnvolymen resulterade i en ökad risk för skada jämfört med ingen förändring av dessa variabler. En idrottare med dessa riskfaktorer, med en genomsnittlig prestationsbaserad självkänsla, hade mer än tre gånger ökad risk för skada jämfört med en idrottare med låg prestationsbaserad självkänsla och ingen förändring i sömn eller träningsvolym. De intervjuade elitidrottarna upplevde en identitetsförlust och beskrev en känsla av att känna sig ensam och utesluten från idrottsaktivitet medan de var skadade. Skillnader i rehabiliteringsförväntningar mellan idrottare och medicinsk personal uppfattades, där vissa idrottare beskrev att deras rehabilitering inte var anpassade för dem och efterfrågade att i en tidig fas efter skada få en skadediagnos.

Slutsats: Ett stort antal elitidrottande ungdomar är regelbundet skadade, vilket leder till allvarliga konsekvenser för idrottarens fortsatta idrottsdeltagande och prestationsförmåga. Idrottsaktivitet verkar utgöra en viktig social mötesplats för elitidrottande ungdomar och skada kan leda till en förlust av identitet och till ensamhet, skuld eller självkritik. Medicinska team, tillgängliga för alla idrottare vid varje Riksidrottsgymnasium, är motiverade för att minska det ohälsosamma beteendet associerad med att vara skadad, förebygga ny skada och hjälpa skadade idrottare att återvända till idrottsaktivitet. De medicinska teamen behöver vara medvetna om de många olika typer av skadekonsekvenser som kan uppstå hos en elitidrottande ungdom.

LIST OF SCIENTIFIC PAPERS

I. von Rosen P, Frohm A, Kottorp A, Fridén C, Heijne A. **Too little sleep and an unhealthy diet could increase the risk of sustaining a new injury in adolescent elite athletes**. Scand J Med Sci Sports. 2016 Aug 19. [Epub ahead of print].

II. von Rosen P, Frohm A, Kottorp A, Fridén C, Heijne A. **High injury burden in adolescent elite athletes: a 52-week prospective study**. J Athl Train. 2017 Jun 20 . [Accepted, in press].

III. von Rosen P, Kottorp A, Fridén C, Frohm A, Heijne A. **Young, talented and injured: Injury perceptions, experiences and consequences in adolescent elite athletes**. Eur J Sport Sci. 2017. [Submitted]

IV. von Rosen P, Frohm A, Kottorp A, Fridén C, Heijne A. **Multiple factors explain injury risk in adolescent elite athletes: applying a biopsychosocial perspective**. Scand J Med Sci Sports. 2017 Feb 16. [Epub ahead of print].

Additional analyses are added in the thesis.

CONTENTS

LIST OF ABBREVIATIONS

ACL	Anterior cruciate ligament
BMI	Body Mass Index
CBSE Scale	Competence-Based Self-Esteem Scale
CI	Confidence interval
HR	Hazard ratio
KASIP project	Karolinska Athlete Screening Injury Prevention project
KSQ	Karolinska Sleep Questionnaire
OR	Odds ratio
OSTRC	Oslo Sports Trauma Research Centre
PSS	Perceived Stress Scale
SNFA Index	Swedish Nutrition Food Agency Index

FOREWORD

I believe my interest in sports medicine brought me to the profession of physical therapy. I guess this was probably the main reason for up to 80% of my classmates joined the program. At that time, I was excited about exploring and understanding sports injuries (yes, I know what a foolish idea). However, I finally matured and eventually, during my bachelor education, became fully aware of that there were far more interesting aspects of physical therapy (like understanding pain and relation to movements) than explaining to a professional high jumper that the reason you have knee pain is likely related to your jump training five days a week, the year around (which the high jumper probably knew). In fact, at that time I totally had forgotten about sport injuries.

Then for some weird circumstance, thanks to two energetic “Piff & Puff” girls, I had an opportunity to join a new project about exploring injuries in adolescent elite athletes studying at National Sports High Schools. A project that a few years later would become the KASIP project (Karolinska Athlete Screening Injury Prevention – I am writing the name here since most of you readers will jump directly to the Acknowledgment section after this part and skip all other boring pages). And as a broke student, together with that I could not leave the other poor fellow student who they also had persuaded, I saw no choice to join the team even though the project seemed organizationally challenging (read impossible). But Piff & Puffs’ smiles, nodding heads and convincing arguments, shook off my doubts.

Anyway, the plot was a bit different and more exciting than I had previously realized. There seemed to be a big black hole with few prospective cohort studies of injury data and few studies that really had target the injury consequences or the perception of injuries in adolescent elite athletes. Case-studies were presented, mostly in the media, about athletes that had to stop their career due to anterior cruciate ligament injuries (the worst knee injury ever – ask my main supervisor) or chronic pain syndromes. However, could this injury picture be generalized to the complete cohort of athletes studying at National Sports High Schools? I doubted this, but had really no idea, and the lack of injury data attracted me. So from there I started my journey in this PhD. Even if the road has been a mix of up and downs I am very grateful I joined this project. Thanks for the adventure!

1 INTRODUCTION

In Sweden, two of three children and adolescents participate in organized sports activities, which contribute to good public health and provide physical recreation, leisure activities, socialization and friendship.[1] Some of the children and adolescents continue their trajectory into elite sports, which is accompanied by greater demands, for example increased training duration, intensity or competiveness, all in an attempt to become top athletes. Consequently, this is likely to increase the risk for musculoskeletal injuries.[2] Even if few prospective long-term studies on injury surveillance in elite adolescent athletes are available,[3] the existing ones have showed a high risk of injury in young athletes.[4-6] In addition, the Swedish documentary "Medaljens pris",[7] which is based on case-reports, and a debate article "Vem tar ansvar för våra elitidrottande barns hälsa?",[8] have highlighted the serious consequences sports injuries may have on youths' physical and mental health.

Severe injuries, such as anterior cruciate ligament (ACL) injuries, are associated with a high re-injury risk and increased risk of osteoarthritis or chronic pain syndromes 10-15 years following initial onset.[9, 10] ACL injury incidence is especially high in female adolescents.[11] Serious injuries, re-injury or fear of re-injury are also likely to cause athletes not to resume their previous level of activity, halt sport participation, and may end their career prematurely.[12, 13] Moreover, an increased professionalization of youth competition has taken place during the last decades,[2, 14, 15] which may have pushed youth sports closer to the sports of adults in terms of competiveness, probably increasing the risk of injury occurrence even more. However, due to the lack of prospective injury registration studies the consequences of injury on health and continued sports participation on performance are less well understood in adolescent elite athletes, in contrast to adult elite athletes.[3] Understanding injury incidence/prevalence, risk factors and injury perceptions among adolescent elite athletes is the first step towards developing effective targeted preventive interventions.[16] This is the main reason for exploring injury data and injury consequences in this population.

1.1 THE THESIS AND PHYSICAL THERAPY

The essence of physical therapy is movement[17] and as stated by Sahrmann,[18] physical therapist's main responsibility is the movement system, which involves both the musculoskeletal and nervous systems, supported by the respiratory, cardiovascular and endocrine systems. Even if movement is not unique to physical therapy it is the cornerstone of the profession and is considered a key objective in promotion, prevention, treatment/intervention, habilitation and rehabilitation.[17] Cott et al.[17] introduced "The movement continuum theory of physiotherapy" in 1995 to present theoretical concepts of physical therapy. This theory is built on three key principles; 1) Movement is essential to human life, 2) Movement occurs on a continuum from movement of molecules, body parts to the whole body in the society, and 3) Movements are influenced by physiological, psychological, social and environmental factors. It is further stated that illness or injury may change the maximum movement potential of an individual. In this thesis, factors that influence movement such as injuries, pain, health factors (e.g. sleep, nutrition), elements of movement (e.g. training factors) and experience/perception of not being able to move normally or not at all, are explored. The different aspects of movement covered in this thesis are therefore well aligned with what physical therapy is about and reflect many of the principles embedded in the movement continuum theory.

1.2 SPORTS PARTICIPATION AND INJURY COSTS

Physical activity and sports contribute to a number of health benefits, such as reducing the risk for cardiovascular disease, diabetes, cancer, hypertension, obesity, depression, osteoporosis and premature death.[19] Despite these positive health effects related to sports participation, sports injuries are common and can lead to reduced participation in sport, and result in work loss and permanent disability in worst cases. Consequently, sport injuries incur great costs to society.[16] Moreover, physical inactivity as a possible consequence of injury has been found to account for 1.5–3.0% of the total direct healthcare costs.[20]

In Sweden, approximately 1 million children and adolescents are involved in organized sports.[21] Every year, about 280 000 persons sustain an injury during physical activity in Sweden, which represents almost half of all emergency visits.[22] Of those injured, approximately 112 000 cases are directly related to sports activities.The direct medical costs for sports injuries are estimated at 1.3 billion SEK per year, not even including costs to rehabilitation, long-term care, transportation, pharmaceuticals, medical devices etc. In addition, costs related to less severe injuries which are not treated in hospitals are not even included in the above mentioned numbers, inferring that the total cost for sports injuries are likely to exceed 1.3 billion SEK per year. The total injury costs related to elite sports activities among adults or adolescents are not known for Sweden since no data on the number of elite athletes and no clear definition of the term “elite athlete” exist. However, if defining an elite athlete as an athlete belonging to the national or international top percentile in a sport, in terms of sports results, a small proportion of all competitors are elite athletes.

1.3 ADOLESCENTS ARE NOT ADULTS

Before the focus of this thesis will change to reflect the field of injuries and injury consequences in sports, it is important to describe the main characteristics of this thesis’s studied population.

Adolescence is defined as the period of transition from childhood to adulthood, often happening between age 13-19 and characterized by rapid physical growth, in which biological, cognitive and psychosocial processes are maturing.[23] During adolescence the body composition changes and a gain in body mass occur, reflecting an increase of fat mass, fat distribution and greater muscle mass.[24] The cognitive maturing is characterized by demonstrating an increased ability for abstract reasoning and logical thinking.[25] Adolescents also engage in a wide range of risk taking, and may therefore be more exposed to harm or accidents than other age groups. It is well known that during adolescence, psychosocial stress may increase, for instance due to conflicts with parents, school, and relationship problems.[26] Also in this life stage the identity exploration and social networking take place which may lead to increased psychosocial stress. The demands on adolescent elite athletes are likely to be similar or even higher among non-athletes of the same age.[27] Factors such as psychosocial stress might be fueled by sport coaches, parents, competitors or from the athletes themselves, e.g. concerning athletic performance expectations.[28, 29]

From a biological perspective, the structural differences of the growing bone, compared to adult bone, may explain why injuries such as epiphyseal fractures, avulsion injuries or apophysitis (e.g. Osgood-Slatter) are more common in adolescents than adult athletes.[24, 30, 31] These injuries are believed to occur to a greater extent in adolescents due to the fact that ligaments tend to be stronger than bone.

It may seem reasonable to translate research findings for adults to adolescents in sports medicine. However, adolescents cannot be compared to adults from a physiological as well as psychological perspective. Caution should therefore be exercised when extrapolating data from adults to adolescents.

1.4 SWEDISH NATIONAL SPORTS HIGH SCHOOLS

Some of the young ambitious adolescent athletes yearly decide to study at a national sports high school in order to improve athletic performance and sport-specific skills. Swedish National Sports High Schools were developed in the beginning of the 1970's, with the aim of providing young athletes an opportunity to combine elite sports and a high school education. The schools are financed by government grants and have employed sport coaches and teachers who are in charge of the sports education. Yearly, 1200 adolescent elite athletes study in Swedish National Sports High Schools. In total, about 50 of these schools are available, offering 30 different sports. The education lasts for three or four years and athletes are typically between 15-19 years of age. Every student has their specific sport code on their schedule, and the long-term goal of the program is to help athletes reaching international elite level in their respective sports. Most students leave home when they are admitted to National Sports High Schools and start living by themselves or together with other athletes close to the schools. This may inadvertently lead to changes in social support, responsibility and increased pressure on oneself as the competiveness increases. Even if National Sports High Schools have been implemented for a long time now and have educated successful athletes, few reports have systematically analyzed the success of these schools in terms of adult level sport results.

1.5 INJURY EPIDEMIOLOGY AND HISTORY

Injury surveillance reports serve as an important step in understanding injury profiles, the incidence and prevalence of injuries, injury trends, and injury prevention. It is particularly useful in serving as a theoretical base for preventive strategies which addresses improvement of sports safety.[3, 32] The first documents of injuries (boxing injuries), have been traced to the historical period of ancient Greece.[33] In sports medicine, one of the first research studies on injuries, covering football players, were published in the beginning of 20th-century.[34] Since then numerous of epidemiologic studies in sports medicine have been performed, where most long-term prospective cohort studies have been conducted from the beginning of the 21th-century.

In previous research, cross-sectional designs have often been used to identify sports injuries, mainly in competition or games.[35-42] Retrospective interviews regarding injury occurrence have been associated with recall bias and have been criticized for not providing accurate data on injury incidence.[43, 44] To minimize recall bias, prospective methods, unlike cross-sectional or retrospective methods, have been recommended.[45] Data from prospective studies are commonly collected through interviews,[46] paper forms,[47] web-based questionnaires[48-50] or text messaging,[51] which are based on reports from medical staff or the athlete. Athlete self-reports have been questioned for subjectivity, although the accuracy of self-report seems to be dependent on the content and how they are implemented.[52] Concerns have also been raised regarding medical personnel who may miss a considerable number of injuries, e.g. due to athletes traveling to competitions/training camps, or for not being able to attend every training session.[43, 53] Besides, not all teams or sport clubs may have resources to allow full access to medical staff.

1.6 INJURY DEFINITION

Defining and classifying injuries are of high importance to accurately describe injury patterns in a sports context.[16] The lack of a clear definition increases the risk of either under- or over-reporting an injury problem which, consequently, will affect the development and effectiveness of preventive strategies.[54] For instance, different injury definitions likely explain the wide variation of the incidence of recurrent injuries, i.e. an injury of the same type and at the same site as a previous injury.[55-58]

A major problem in sports injury epidemiology is that no single consensus on the definition of an injury exist.[59] Instead, consensus reports have been published separately for different sports and are available for football,[60] rugby,[61] tennis,[62] thoroughbred horse racing[46] and athletics,[63] for example. A similar issue exists for classifying subsequent injuries, defined as the second injury irrespectively of the occurrence and relation to previous injuries,[64] where various proposals to classify subsequent injuries have been suggested.[65, 66] The first published injury consensus report[60] defined a sport injury in football as:

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

As outlined by Bahr,[45] this definition covers three different injury definitions: "any physical complaint", "medical attention injury" and "time loss injury". The choice of injury definition will highly influence the reported injury rate, where the option "any physical complaint" definition is likely to identify the highest number of injuries, followed by injuries that have received "medical attention" and then only injuries based on "time loss" from sports (Figure 1). For instance, by comparing self-reported data on injuries with records of time-loss injuries, as recorded by medical staff, athlete self-report more than ten times as many injuries compared to that reported by medical staff.

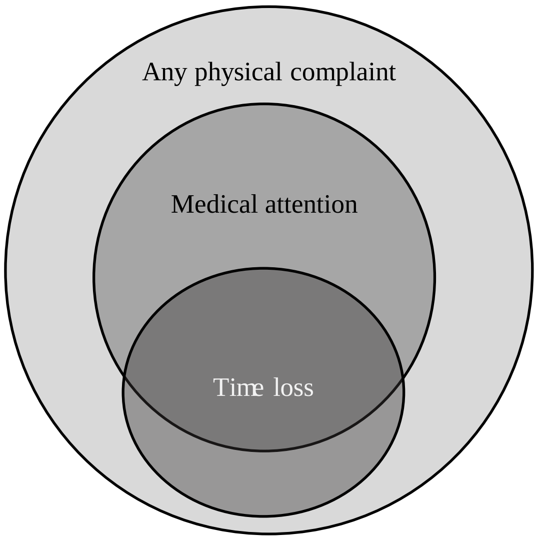


Figure 1. Venn diagram over a supposed distribution of the number of injuries for each injury definition, based on the consensus report of Fuller et al.[66] and Clarsen et al.[89].

Injuries could further be classified according to its onset or in the order an injury occurs. In the consensus statement of football,[66] an acute or traumatic injury refers to an injury resulting from a specific, identifiable event, whereas an overuse injury or a gradual onset injury refers to an injury caused by repeated micro-trauma without a single, identifiable event. In the consensus statement of athletics, injuries are categorized into gradual or sudden onset. Sudden onset injuries are then subcategorized into traumatic injury versus overuse injury, based on the fact if the injury is related to an identifiable single external transfer of energy or not.[63]

In the consensus statement of football, Fuller et al.[66] defined a recurrent injury as:

"An injury of the same type and at the same site as an index injury and which occurs after a player's return to full participation from the index injury. A recurrent injury occurring within 2 months of a player's return to full participation is referred to as an ''early recurrence''; one occurring 2 to 12 months after a player's return to full participation as a ''late recurrence''; and one occurring more than 12 months after a player's return to full participation as a ''delayed recurrence''.

Different injury definitions, data collection modes and analysis methods highly influence the results of injury surveillance. These design differences make the comparisons or interpretation of published injury data among studies difficult or even impossible.

1.7 PREVENTION OF SPORTS INJURIES

Due to the physical and psychological consequences of injuries and its associated financial costs, injury prevention is a top priority. Van Mechelen et al.[16] emphasized that without knowledge of the incidence, etiology and mechanism of injury, it is not possible to effectively prevent sports injuries. Therefore, the "sequence of prevention" was introduced, describing necessary steps in injury prevention (Figure 2). Firstly, the model emphasizes that the injury problem in terms of incidence and severity measures is identified. Secondly, risk factors and injury mechanisms must be identified. Thirdly, preventive measures, based on information from the first and second steps, are implemented. Finally, the first step is repeated to conclude on the effectiveness of preventive measures, preferably through randomized clinical trials. Finch[67] expanded the model to consider the context in which interventions are to be implemented to ensure uptake of the interventions in a real-world context. Therefore a new research framework, the Translating Research into Injury Prevention Practice framework (TRIPP), was introduced, capturing additional and expanded steps. This new framework does also take into account contextual and sport-specific factors which may influence the effectiveness of a preventive measure. These factors could, for example, be adopted safety behaviours or knowledge and attitudes of players, coaches and sports bodies about the proposed preventive actions.

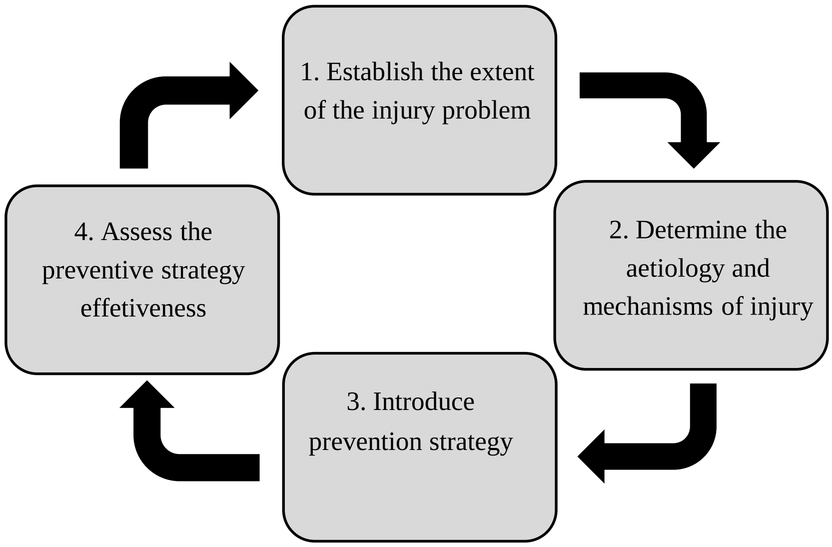


Figure 2. The "sequence of prevention" of sports injuries (redrawn from van Mechelen et al.[16]).

In a systematic review aiming to investigate different preventive strategies, McBain et al.[68] found that only 14% of the studies, included children and adolescents under the age of 18 years. Most injury prevention reports of adolescent athletes included football players, mainly female athletes, and focused on serious knee injuries.

1.8 INJURIES IN ADOLESCENT ELITE ATHLETES

Even though the injury risk is likely to be higher in elite adolescent athletes than in non-elite adolescent athletes, most likely due to more intensive training and tougher competiveness in sports, the majority of systematic injury surveillance reports have mainly been performed in recreational athletes.[69-72] In addition, most studies have included adult elite athletes instead of adolescent elite athletes.[73-79]

In an injury prevention approach the recommendation has been to follow athletes over a full season to accurately determine the injury problem.[45] However, only a few long-term (≥26 weeks) prospective injury reports of adolescent elite athletes are present in the scientific literature.[3] Long-term prospective injury surveillance studies, including adolescent elite athletes, are available for alpine skiing,[5] athletics,[49] football,[4, 80, 81] gymnastics,[82, 83] handball[6, 84] and orienteering (Table 1).[50] The injury incidence has varied between 1.4-18.0/1000 hours of training and up to 22.4/1000 hours of competition across reports. However, comparing injury data between these sports might be difficult since the injury definition used may vary greatly. For instance, in Le Gall et al.,[4] a time-loss definition of an injury was used, whereas in Jacobsson et al.,[49] all injuries that partially or completely hindered athletes from training and competition were recorded.

Table 1. Prospective reports (≥26 weeks) of injury data on injury location and injury incidence for adolescent elite athletes.

Authors	Population	Sports	Follow-up, data collection	Injury locations[a]	Injuries per athlete per season	Injury incidence per 1000 hours
Jacobsson et al.[49]	n=126, age 17	Athletics	1 year, self-report	Knee, lower leg, foot	1.0	2.8
Kirialanis et al.[82]	n=162, mean age 13	Gymnastics	1 year, medical staff	Foot, knee-thigh, hand	0.9	
Kolt & Kirkby,[83]	n=64 (elite=24) age 11-19	Gymnastics	18 months, self-report	Foot, lower back, knee	4.2	2.6
Le Gall et al.[80]	n=528 age 14-16	Football	10 years, medical staff	Thigh, foot, knee	0.3	4.8
Le Gall et al.[4]	n=119 age 15–19	Football	8 years, medical staff	Foot, thigh, knee	0.7	6.4
Möller et al.[6]	N=346 age 16-18	Handball	31 weeks, self-report	Ankle, lower leg, knee	1.3	5.9
Möller et al.[84]	n=679 age 14-18	Handball	31 weeks, self-report/medical staff	Shoulder (no other data collected)	0.3 (shoulder data)	1.4 (shoulder data)
Price et al.[81]	n=4773 age 9–19	Football	2 years, medical staff	Thigh, foot, knee	0.4	
von Rosen et al.[50]	n=64 age 15-19	Orienteering	26 weeks, self-report	Foot-lower leg, knee, hip	3.4	18.0
Westin et al.[5]	n=193 age 15-19	Alpine skiing	5 years, self-report	Knee, spine, hand	0.4	1.7

[a] Top three (ranked) injury locations with highest injury incidence

Several reports following a large number of high school and college athletes, including both elite and non-elite athletes (Table 2), have been published.[46, 85-87] In these studies, the overall injury incidence rate has varied between 1.3-6.3/1000 competitions/training sessions. The injuries have been reported by medical staff, mostly using the time-loss definition.[85, 86, 88] It is however possible that the number of reported overuse injuries might be underestimated by using the time-loss definition, as well as the overall injury rate.[89]

Table 2. Prospective reports (≥1 year) of injury data on injury location, injury incidence, presented for college/high school athletes.

Authors	**Population**	**Sports**	**Follow-up, data collection**	**Injury location**[a]	**Injury incidence per 1000 hours**
Dick et al.[87]	n>33 000 college athletes age 18-22	Lacrosse	16 years, medical staff	Foot, thigh, knee	3.3[b]
Fernandez et al.[46]	n=100 high schools age 15-18	9 different sports	1 year, medical staff	Foot, knee, upper leg	1.3[b]
Hootman et al.[88]	College age 18-22	15 different sports	16 years, medical staff	Knee, ankle, upper extremity	4.0[c]
Yang et al.[86]	n=573 college athletes age 18-22	11 different sports	3 years, medical staff	Knee, lower leg-foot, torso	6.3[b]

[a] Top three (ranked) injury locations with highest injury incidence
[b] Injury Rate per 1000 Athlete-Exposures (one athlete participating in one game or practice)
[c] Injury Rate per 1000 Athlete-Exposures (one athlete participating in one practice)

1.9 PSYCHOLOGICAL INJURY CONSEQUENCES

During injury the athlete may have to face different scenarios, in terms of mandatory rest and surgical interventions, and may also experience lack of control over one's life situation. Those athletes who are used to the mentality of "no pain, no gain" may need to change their state of mind in order to optimize the transition back to sport activity. These consequences create stressful and possibly new and adverse situations for the athlete, which could lead to psychosocial disturbances such as low mood or depression.[90, 91]

In an interview report of college athletes it was concluded that the onset of injury was associated with experiences of negative thoughts and feeling of depression.[92] This was further confirmed in another interview study,[93] involving eight previously injured college athletes age 18-22, where injury was predominately associated with emotions such as being upset, in shock and feeling hysterical. During the rehabilitation phase, athletes reported more optimism and diligently attended rehabilitation in order to fully return to sports. Seeking social support from family and others seems to be a common strategy to handle injury emotions. Other emotional responses to injury often include tension, anger, low self-esteem and anxiety.[94]

In the integrated model of psychological response to sport injury by Wiese-Bjornstal et al.,[95] it is suggested that personal (e.g. history of injury, coping skills) and situational factors (e.g. social support, coach influence) affect the individual's cognitive appraisal, i.e. how athletes respond and react to an injury (Figure 3). Cognitive appraisal (e.g. rate of perceived recovery, goal adjustment, cognitive coping) is then influencing the emotional (e.g., depression, anger) and behavioural response (e.g., use of coping skills, adherence to rehabilitation, goal-setting) in a reciprocal process, affecting the physical and psychological recovery outcomes. Wiese-Bjornstal et al.[95] emphasized that the response to an injury is dynamic and changeable over time. The integrated model of psychological response to sport has been found to be consistent with perceptions of elite athletes of age 18-22.[96]

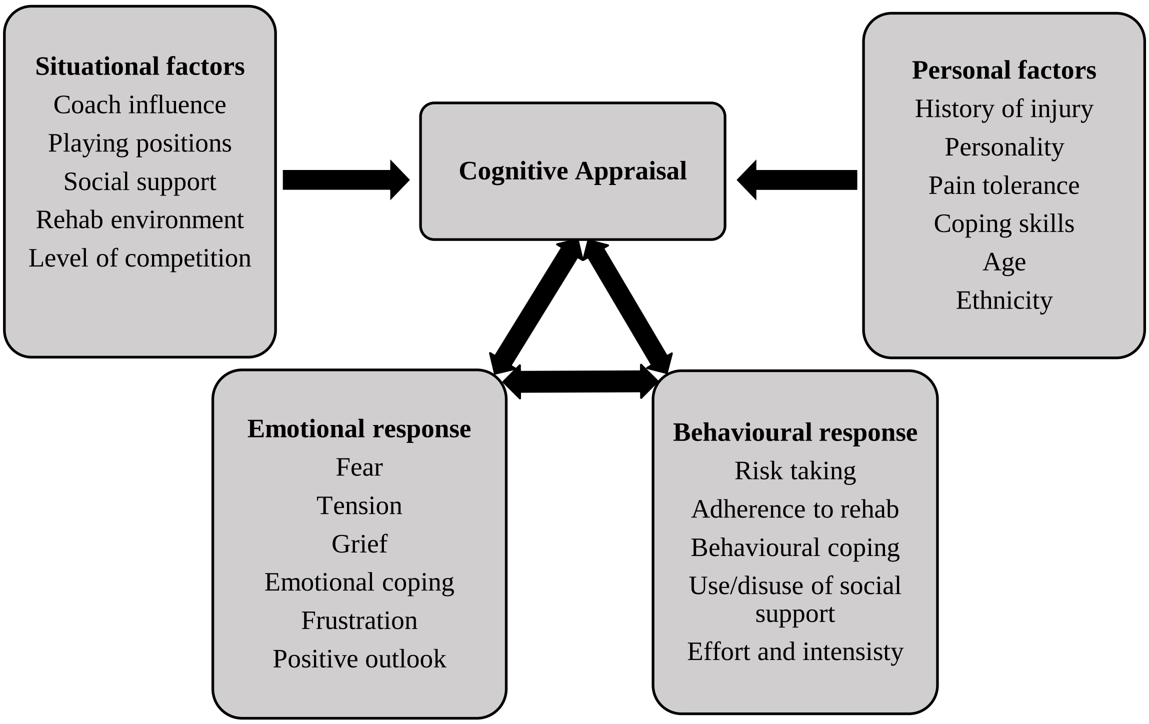


Figure 3. The integrated model of psychological response to sport injury (redrawn from Wiese-Bjornstal et al.[95]).

Returning to sports activity and recovery after injury is associated with several psychological factors.[97] Social support has been found to be associated with both coping and rehabilitation following sport injury.[92, 98, 99] Other psychological responses, such as motivation, confidence and low fear, have shown to be associated with preinjury level of participation and prompt return to sports activity in adults.[97] It is unknown to what extent this is true for adolescent elite athletes.

1.10 INJURY RISK FACTORS

Identifying risk factors is a crucial step in injury prevention.[16] The aetiology of sports injuries is multi-factorial, involving both internal and external risk factors.[100] Internal risk factors refer internal to the athlete (e.g. age, sex, injury history, biomechanics), whereas external risk factors act on the athlete from outside (e.g. environment, sports equipment, sports rules). Some of these risk factors may be modified (e.g. workload, equipment), whereas other are non-modifiable (e.g. sex, age).

A model describing injury causes, firstly described by Meeuwisse[101] and later expanded by Bahr & Krosshaug,[100] aims to explain and clarify why certain athletes are at greater risk for injuries and how injuries occur (Figure 4). In this model, internal and external risk factors increase the risk of injury occurrence. However, the presence of internal and external risk factors in an athlete does not explicitly explain injury occurrence, but may only render an athlete susceptible to injury. For the injury to occur, an inciting event (the injury mechanism) also needs to take place as the final event that causes an injury, according to Meeuwisse.[101] This event could be a tackle leading to a shoulder injury in a handball player or a training program causing a stress fracture in a triathlon athlete. Often, the inciting event is associated with the onset of acute injury, but could also be more distant for the onset of overuse injuries.

Bahr & Krosshaug[100] argue for the importance of a comprehensive description of the injury mechanism by including an understanding of the injury situation (e.g. playing situation, opponent behaviour) and the biomechanics of the whole body and joints before and at the time of injury. Meeuwisse et al.[102] have later expanded the model by taking into account that risk factors and injury aetiology change over time in dynamic, recursive cycles. Even though this approach may complicate data analysis, it might accurately reflect the true nature of injury aetiology and account for the happenings after the injury. Finally, to understand how risk factors are interacting, the researcher needs to be aware of interaction between risk factors and possible confounding variables in order to fully understand the complex injury process.[103]

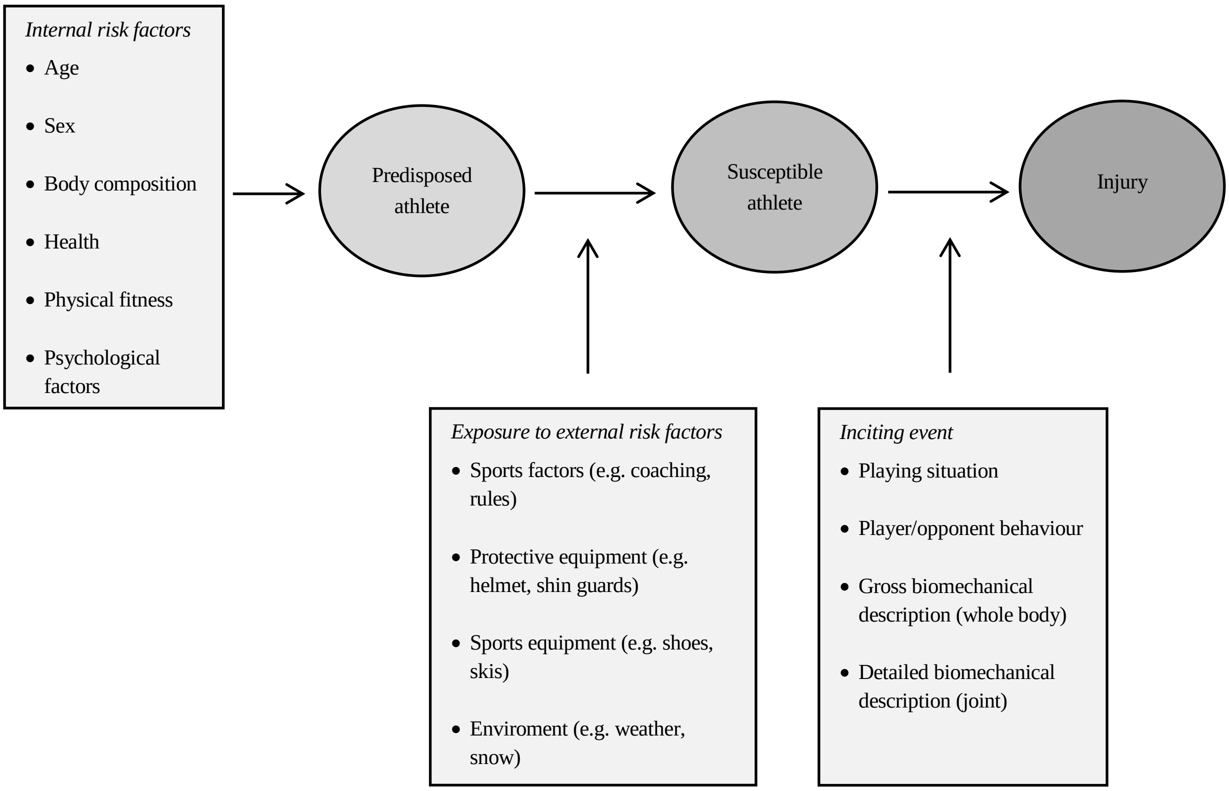


Figure 4. Model for injury causation (redrawn from Bahr & Krosshaug[100]). Internal risk factors predisposed the athlete for an injury. Adding external risk factors make the athlete susceptible to injury and finally in order for the injury to occur an inciting event is needed.

Apart from within football, there are limited studies in the scientific literature on injury risk and risk factors in adolescent elite athletes.[3] Besides, many risk factors have been suggested, with little consistency between studies.[104] Reports of internal risk factors have shown that previous injury is to be considered a risk factor for a subsequent injury, for example in tennis,[105] athletics[49] or football,[106] and for a more severe injury.[107, 108] Sex differences in injury risk have also been explored, where females seem to have a greater risk than male adolescents for a number of injuries, such as stress fractures, ACL injury and anterior knee pain.[31, 109] Regarding external risk factors, different aspect of training load have been implicated as injury risk factors. A high training load or match-play,[110-115] increased ratio of acute and chronic training load[116] and a high training load Index[49] (combination of training hours and intensity) are associated with an increased risk of injury.

Health variables, such as nutrition, sleep, self-esteem and self-perceived stress, which is believed to be of importance in athletic performance,[117-119] are not frequently reported and studied as risk factors for injury in young athletes. A healthy diet likely enhances recovery between training sessions and competitions, and thereby reduces the risk of injury and illness.[46, 120, 121] Besides, the diet seems to have a decisive impact on female development of the Female Athlete Triad, i.e. a syndrome consisting of eating disorders, menstrual disorders and decreased bone mineral density.[122] The prevalence of the Female Athlete Triad has been found to be high in sports that emphasize leanness, such as in dance or running.[123, 124]

The optimal sleep volume as a precursor for injury remains inconclusive.[118] However, a lack of sleep has been associated with developing depression, anxiety, and suicidal tendencies among adolescents.[125] In sports, Milewski et al.[126] showed that a decrement in sleep increased the risk of injury in young athletes. Self-esteem, defined as a personal judgement of one's worthiness, has been associated with eating disorders, depression, antisocial behaviour, poorer mental and physical health,[127, 128] but has not been studied in relation to injury occurrence. Several psychological variables, such as irritability,[129] self-blame,[130] negative life-event stress,[131, 132] as well as self-perceived stress or daily hassles have been associated with injury risk in sports.[133-136] Increased distractibility, fatigue and reduced coordination are examples of mechanisms stress induce injury risk.[137]

In summary, the most conclusive risk factor seems to be previous injury in young athletes. Still, most studies have focused on a limited number of risk factors, instead of included multiple variables in one model, leading to gaps in our understanding about the interrelationship between multiple risk factors.[103]

1.11 BIOPSYCHOSOCIAL PERSPECTIVE

George Engel presented the biopsychosocial model in 1977 to offer an alternative perspective to the biomedical model.[138] At that time, the current biomedical model focused purely on biological aspects of the disease, where psychological aspects were completed ignored. Engel argued, in order to understand the causes of disease, clinicians need to consider the patient, the social context of the patient and the society surrounding the patient. The biopsychosocial model accounts for both biological (e.g. age, sex), psychological (e.g. mood, stress) and social factors (e.g. culture, socioeconomic), and the interaction among these. It is clear that the biopsychosocial model have influenced Cott et al.[17] theory about the movement continuum.

To illustrate the differences between the biomedical and biopsychosocial models an example in a sports context is presented here. A football player suffers an intraarticular knee injury during a game, which in a biomedicine model may be seen as a result of extensive knee motion, impairment of knee coordination or knee joint instability. Using a biopsychosocial model may, in addition to previous factors, address cultural aspects in the football team (social factors) or the well-being of the player (psychological factors) before injury, to mention a few. For example, the competiveness of the football team may have pushed the player to work hard in order to earn a place in the starting line-up of the team, resulting in an aggressive playing style or a physical and mental tired player, leading to an increased injury risk.

The biopsychosocial model may therefore offer a more holistic view of injury risk, which considers other factors than biological aspects as presumed within the biomedicine model. However, the biopsychosocial model has been criticized for introducing subjectivity, having unclear boundaries between biological, psychological, social factors, and for lacking clear frames in the analytic approach.[46] Even so, exploring other factors, than biological aspects, may contribute to our understanding of other factors of injury risk which may be as relevant as the more commonly explored biological factors. In this thesis the biopsychosocial perspective was chosen, in order to understand injury risk factors (Figure 5).

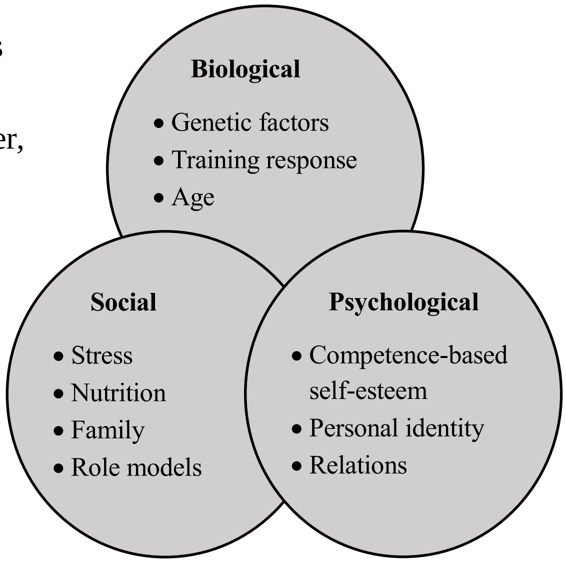


Figure 5. Examples of factors in the bio-psychosocial model (redrawn from Engel[138]).

1.12 THESIS RATIONALE

There are few longitudinal injury surveillance reports following adolescent elite athletes from multiple sports, and therefore data on injury incidence/prevalence, risk factors and injury perceptions and experience are lacking. Of the sparse literature, studies have shown high injury incidence in certain sports of adolescent elite athletes.[4-6, 84] Besides, a systematic review,[2] an opinion article[8] and a documentary[7] have highlighted the serious consequences sports injuries may have on adolescents' physical and mental health. Therefore, multiple reasons exist to explore injury data in this population. In addition, in order to effectively prevent sports injuries, and their serious consequences we need to have data, for example, on injury prevalence/incidence, injury locations and risk factors for injuries.[16] Without reliable data, injury prevention will be an inefficient guessing game.

Exploring health variables such as perceived stress, nutrition, self-esteem, and sleep in adolescent elite athletes may contribute to our understanding of the life situation of being a young elite athlete. It may also identify health-related markers associated with injury risk and performance as well as unhealthy behaviours.[46, 117, 139] More in-depth knowledge of athletes' injury experience and perceptions may further increase our knowledge of rehabilitation approaches in treating young elite athletes and possibly lead to identifying gaps in the rehabilitation chain and areas in need of improvement. Since, most of the research has focused purely on adult elite athletes, a young elite athlete perspective is required. For instance, we do not know the true injury burden in young elite athletes. We also have limited knowledge of the physical and psychological consequences of injuries in this population. Finally, factors which may render a young elite athlete susceptible to injuries are also not clear. Consequently, these knowledge gaps hamper development of injury prevention programs. Exploring injury data, risk factors and injury consequences in adolescent elite athletes, using prospective data collection methods, interview methods, are therefore of high relevance from a health as well as sports performance perspective and may lead towards more effective injury prevention measures.

2 AIMS

The overall aim was to explore injury patterns, training and health variables such as nutritional behaviour, self-esteem, sleeping habits, self-perceived stress, and to identify risk factors for sustaining a sport injury among adolescent elite athletes. Further, to explore consequences of sport injuries and athletes' perceptions and experience of being injured.

2.1 SPECIFIC AIMS

Study I: To present overall data on self-perceived stress, nutrition intake, self-esteem, and sleep, as well as sex and age differences, on two occasions among adolescent elite athletes. A secondary aim was to study these health variables as potential risk factors on injury incidence.

Study II: To describe injury patterns in terms of injury type, location, prevalence/incidence, recurrence, severity grade of injuries, time to first injury and prevalence of illness. A secondary aim was to compare differences in injury data by sex and sports types.

*Study III: T*o explore, in-depth, data on injury consequences and adolescent elite athletes' perceptions and experience of being injured.

*Study IV: T*o identify risk factors for injury in adolescent elite athletes, using a biopsychosocial approach.

3 METHODS

This thesis is part of the larger KASIP (Karolinska Athlete Screening Injury Prevention) project, which aims to understand injury occurrence and associated risk factors in Swedish adolescent elite athletes. Both quantitative and qualitative methodologies are utilised in this thesis (Table 3).

Table 3. Methodology of included studies in this thesis.

	Study I	Study II	Study III	Study IV
Design	Cross-sectional, prospective cohort	Prospective cohort	Qualitative, prospective cohort	Prospective cohort
Outcome measures	CBSE Scale, injury, PSS, sleep, SNFA Index	Injury type, injury location, injury prevalence/incidence, prevalence of illness, relative impact of injuries, time to first injury	Injury prevalence, perceptions and experience of being injured	First reported new injury
Data collection	Web-based questionnaire, two occasions year one	Web-based questionnaire year one	Interview, Web-based questionnaire year two	Web-based questionnaire year one and two
Sample size (n)	340	284	340	496

CBSE Scale, The Competence-Based Self-Esteem Scale; PSS, The Perceived Stress Scale; SNFA Index, The Swedish Nutrition Food Agency Index

3.1 PARTICIPANTS

Recruitment of participants was performed once a year over two years (autumn 2013, autumn 2014). At year one, the National Federation of Basketball, Skiing, Orienteering, Handball, Volleyball, Tennis and Athletics were invited to an information session about this project. The Volleyball, Tennis and the Basketball Federations rejected participation, mainly due to their involvement in other similar projects. During the second year, all other National Federations in Sweden, those not contacted during the first year, were invited to participate. This resulted in acceptance from the National Federation of Water ski, Canoe, Rowing, Wrestling, Bowling, Triathlon, Golf, Cycling and American football.

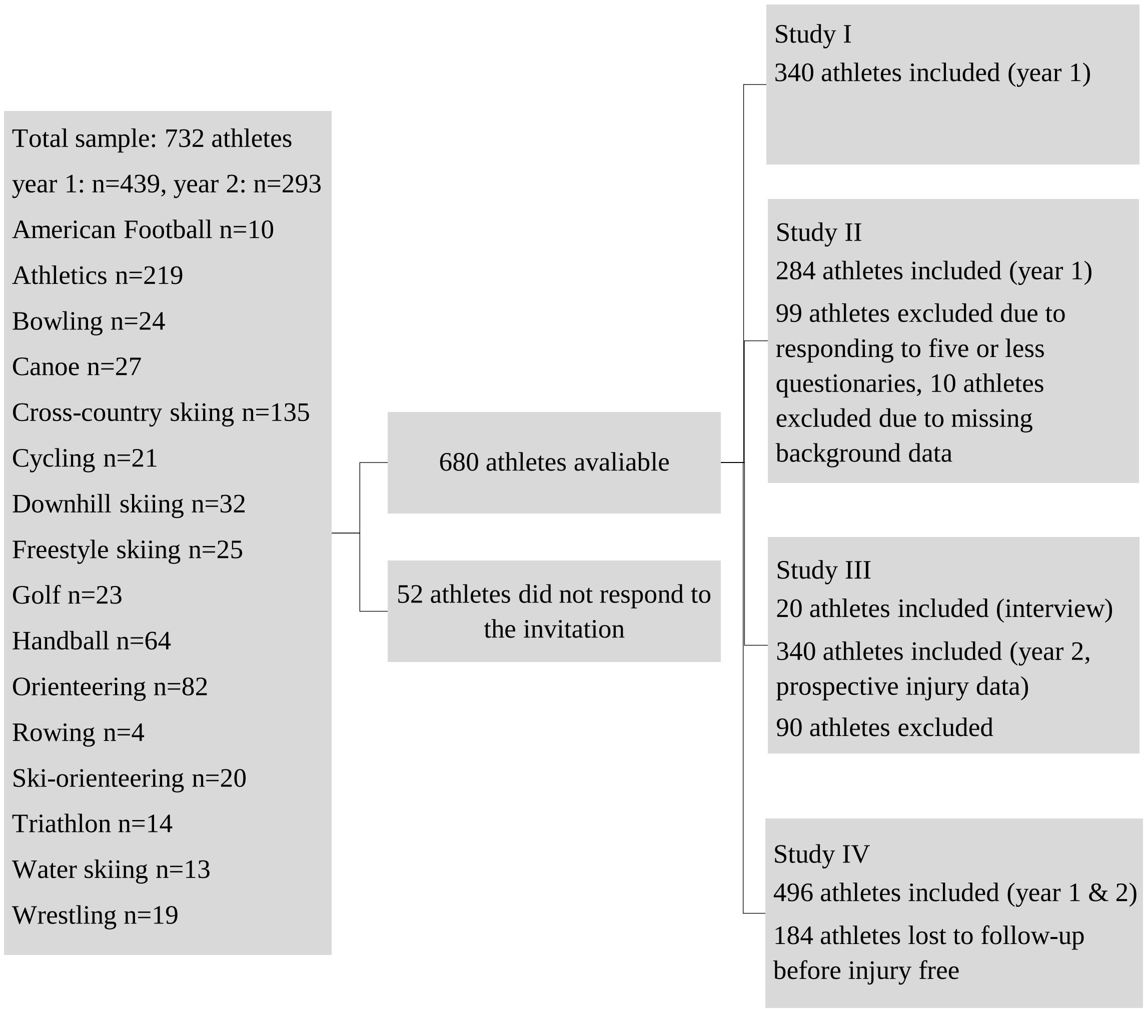


Figure 6. Flowchart illustrating the recruitment of athletes in each study.

In all, 16 different sports, across 24 National Sports High Schools were invited to participate (Figure 6). The available cohort consisted of 732 adolescent elite athletes (age range 15-19), of which 680 unique athletes, accepted to participate in at least one of the four studies.

In study I, athletes who had completed one of the two background questionnaire were included. In study II, athletes who were followed during year one and in study III, those athletes followed during year two, were included. For the focus group interviews (study III), the inclusion criteria were as follow: 1) adolescent elite athletes studying at a Swedish National Sports High School, 2) have had an injury that affected participation in their main sport, resulting in reduced training volume, experience of pain or reduced performance in sports, for at least four continuous weeks in the last year. In study IV, non-injured athletes at the start of year one and two were included. Injured athletes were followed until they reported injury-free status for a continuous period of four weeks, at which point they were eligible for inclusion. Having this criterion resulted in in the exclusion of 184 athletes due to constant reporting of injury.

In study II, athletes were excluded from data analysis if they failed to complete the background questionnaire and in study III if responded to less than 10% of the weekly/bi-weekly questionnaires. The rationale for this was to have a constant report of injury data throughout the season, necessary for avoiding a biased result among non-responders and to provide a valid picture of the burden of injuries. Subgroup analyses were executed to explore if the excluded athletes differed from the main cohort under investigation. These showed no systematic difference with respect to sex, sports participation (study II), sex (study III), and injury history (study IV), except that the drop-outs were associated with athletics athletes in study IV. In Table 4, background data are presented for the included athletes.

In study II, based on sports characteristics and physiological demands (anaerobic, aerobic, power, athletes with a mix of these qualities), athletes were grouped into the following five different types of sports; Sprint athletes (sprint athletic athletes, freestyle skiers, downhill skiers), Power athletes (jumpers, throwers and combined events athletics athletes), Endurance running athletes (orienteers, middle- and long-distance runners), Endurance skiing athletes (cross-country skiers, ski orienteers) and Handball players.

Table 4. Demographics presented with mean (SD), if not stated otherwise, for athletes in study I-IV who have completed the background questionnaire.

	All athletes	Females	Males
Sex, female/male, n (%)	298/350 (46.0/54.0)	298/- (100.0/-)	-/350 (-/100.0)
Age (year)[a]	17 (15-19)	17 (15-19)	17 (15-19)
BMI	21.8 (2.3)	21.3 (2.2)	22.2 (2.3)
Training sessions/week during base training	4.8 (1.4)	4.6 (1.3)	4.9 (1.5)
Training sessions/week during competitive season	4.3 (1.4)	4.2 (1.3)	4.5 (1.4)
Rest days/week during base training	2.5 (0.9)	2.5 (0.9)	2.4 (0.9)
Rest days/week during competitive season	2.6 (0.9)	2.7 (1.0)	2.6 (0.9)
Injured at start of study, n (%)	212 (32.7)	106 (35.6)	106 (30.3)

[a]median values (range)

*32 athletes with missing demographics data due to failing to complete the background questionnaire

3.2 PROCEDURES

The National Sports High Schools of the Sports Federations that were interested in participating in the KASIP project were contacted. All the contacted high schools accepted the invitation. Following acceptance, they were then visited by at least one of the members in the KASIP research group. The coaches and athletes were orally and verbally informed about participation in the KASIP project and written consent was then obtained from the athletes. The athletes were followed between 2013-2014 and 2014-2015, with the study ending in December 2015. Web-based questionnaires were used to collect data over this period. Due to changes in the questionnaire distribution rate between year one and two, the term time point is used in this thesis to describe an occasion the questionnaire was distributed (Year one, 52 time points; Year two, 26 time points).

3.2.1 Paper I

In study I, data on the first two background questionnaires (see below) distributed during the first year were analysed in order to present descriptive data on self-perceived stress, nutrition intake, sleep, self-esteem, as well as to identify risk factors for injury. This resulted in athletes being followed over two time points. The uninjured athletes at the first time point were followed up to the second time-point to identify risk factors for injury incidence.

3.2.2 Paper II

This study was based on injury data collected during the first year in the KASIP project, including 52 time points. Data on injury type (recurrent injury/non-recurrent injury), injury location, injury prevalence/incidence, severity grade of injuries, time to first injury and prevalence of illness, were presented. Athletes were divided into five sports type groups in order to interpret the injury data more comprehensively. The five groups were; Sprint athletes (sprint athletic athletes, freestyle skiers, downhill skiers), Power athletes (jumpers, throwers and combined events athletics athletes), Endurance running athletes (orienteers, middle- and long-distance runners), Endurance skiing athletes (cross-country skiers, ski orienteers) and Handball players. Injury data were compared by sex and sports types. Subgrouping athletes in sports types was based on sports' characteristics and physiological demands of each sport. Since three sports (downhill skiing, freestyle skiing, ski orienteering) had small sample sizes with less than ten participants in each, and involved athletes with highly different characteristics (like athletic athletes), this was considered necessary for meaningful data interpretation.

3.2.3 Paper III

In study III, injury data were collected over 26 time points during the second year along with collection of interview data on injured athletes. The prevalence of injury, substantial injury and injury consequence variables (sport participation, performance, training and pain) were determined. Furthermore, interview data were collected using a semi-structured interview guide. The interview guide consisted of questions about the period before injury, while injured and post-injury, while using open-ended questions in order to gain a broad overview of characteristics and experiences. After conducting two pilot focus group interviews, questions were added about social support and injury consequences. The interviews were tape recorded, lasted between 25-42 minutes (average 29 min), and was carried out by a physiotherapist with clinical experience in sports medicine.

3.2.4 Paper IV

Risk factors for the first reported injury were explored based on injury reports from athletes which were followed over the two seasons (2013-2015). Only non-injured athletes were included in the data analysis and contributed with observation time. The injured athletes (n=393, 57.8%) as of the start of the study, were followed until they reported four continuous weeks of full participation in normal training or competition, with no reduced performance level or reduction in training volume or experience of pain. Only after such confirmation, athletes were included in the study.

3.3 QUESTIONNAIRES

Two types of questionnaires were used in this thesis; a background questionnaire and a weekly/bi-weekly (year one/year two) web-based questionnaire. These questionnaires were sent by e-mail utilizing the software Questback online survey (Questback V. 9.9, Questback AS, Oslo, Norway). The background questionnaire was distributed at the start of the study and at the beginning of the subsequent terms over the following two years. It contained personal data questions (age, sex, anthropometrics, sports participation, training variables, alcohol intake etc.), as well as valid and reliable sub-questionnaires investigating sleep,[140] self-perceived stress,[141] nutrition[142] and competence-based self-esteem.[143]

The web-based questionnaire contained the translated, valid, reliable version of the OSTRC (*Oslo Sports Trauma Research Centre*) Overuse Injury Questionnaire[89, 144, 145] as well as questions used by Jacobsson et al.[49] in an athletic surveillance study. It consisted of three parts: 1) questions about training variables, prevalence of injuries and illness, based on the OSTRC Overuse Injury Questionnaire[89] and Jacobsson et al.[49], 2) questions about new injury occurrence, described by Jacobsson et al.[49] and 3) questions about return to sport after an injury, also by Jacobsson et al.[49]. The OSTRC Overuse Injury Questionnaire addresses injury consequences on sports participation, performance, training and pain in different body regions, using four questions with alternative responses (Figure 7). Specifically, it assesses the effect of injuries on participation (four alternative responses ranging from “full participation” to ”cannot participate”), reduction in training volume (five alternative responses ranging from ”no reduction” to ”cannot participate”), reduced sporting performance (five alternative responses ranging from ”no effect” to ”cannot participate”) and experience of pain (four alternative responses ranging from ”no pain” to ”severe pain”). Questions about training volume, participation in competition events and general well-being, were added (Appendix).

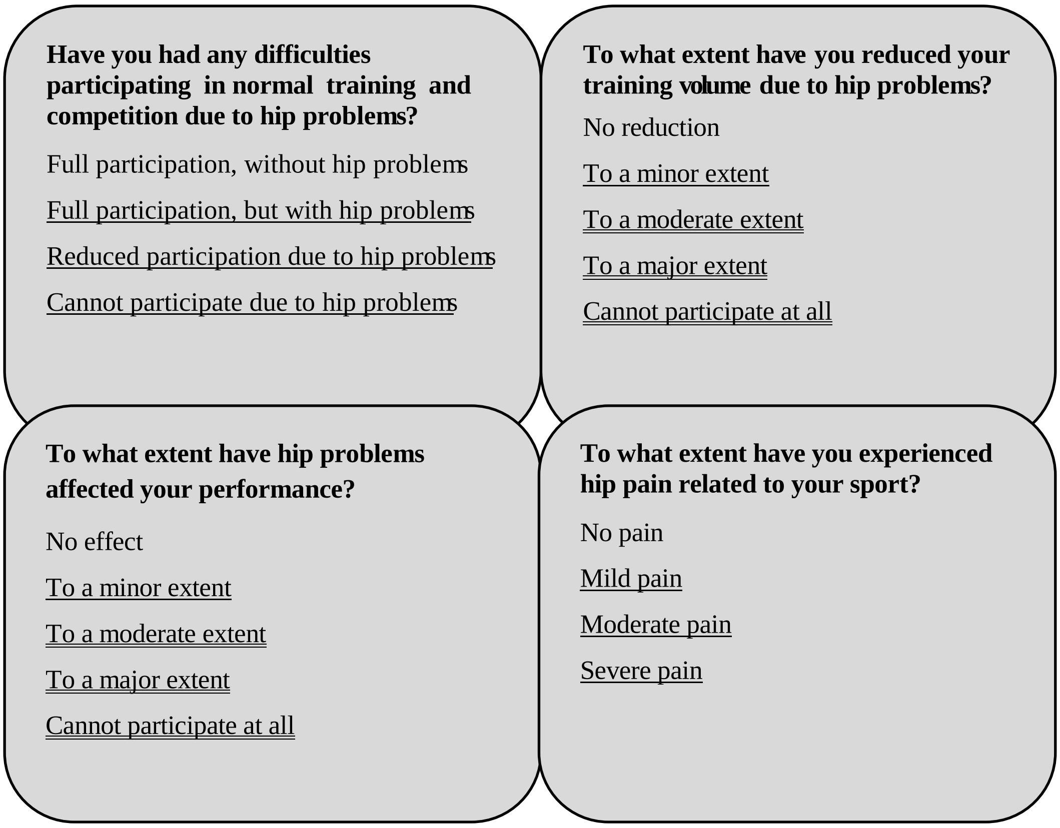


Figure 7. Examples of questions used for an athlete with an assumed hip injury. Marking at least one alternative with one line is defined as having a hip injury, whereas marking at least one alternative with a double line stands for having a substantial hip injury.

Specifically, part two of the questionnaire addresses injury situation (training/competition), circumstances, injury site, injury onset and injury history, whereas part three concerns returning to sports after injury and involve time away from normal sports participation, medical assessment and treatment. Jacobsson et al.[49] developed this questionnaire from the original injury report by the soccer consensus group and International Olympic Committee group.[60, 146] The feasibility of the questionnaire has been determined during the World Championships in athletics,[37] however, the reliability and validity has not yet been explored to date.

The weekly/bi-weekly web-based questionnaire was distributed weekly, over 52 time points, for year one and bi-weekly, 26 times points, over year two. Distributing the questionnaire bi-weekly during the second year was decided upon in order to improve the response rate. The average response rate in year one and two was 60.0% (95% CI 57.4-62.6) and 58.4% (95% CI 55.2-61.6), respectively.

3.4 OUTCOMES

3.4.1 Injury

The athletes were asked to report a new injury as any new physical complaint that affected participation in normal training or competition, resulted in reduced training volume, experience of pain or reduced performance in sports.[89] The athlete was reported to be injured when reporting any physical complaint, irrespective if it is a new or previously reported episode, that affected participation in normal training or competition, resulted in reduced training volume, experience of pain or reduced performance in sports. Operational definitions of injury, substantial injury, recurrent injury and illness are presented in Table 5. The proportion of athletes reported injury which affected participation in normal training or competition, resulted in reduced training volume, performance, or experience of pain, was determined and presented as four injury consequence variables.

Injury data were also presented by injury location, time to first injury and severity grade. To determine the severity grade, the alternative responses in the four questions of the OSTRC Overuse Injury Questionnaire were allocated a numerical value from 0 to 25, where 0 represents no injury and 25 maximum severity. Questions with four alternatives were scored 0-8-17-25, and questions with five alternatives were scored 0-6-13-19-25, following the approach in Clarsen et al.[89]. The four questions were then summed to a severity score. Consequently, a score of 0 represented no injury and 100 the highest degree of severity. The severity grade was then determined by adding the severity score for each injury location. The sum was then divided by the total number of responders to represent the relative impact of injuries in each body site for all athletes.

Injury severity was also determined based on the time absent from normal training due to a new injury. After the athletes had recovered from a new injury, the injury was classified as: minor which led to 1–7 days absence from normal training; moderately serious- 1 to 4 weeks absence from normal training; serious- >28 days–6 months absence from normal training; long-term- >6 months absence from normal training.[147]

Table 5. Operational injury and illness definitions.

Injury	Any physical complaint resulting in reduced training volume, experience of pain, difficulties participating in normal training or competition, or reduced performance in sports.
Substantial injury	Any physical complaint resulting in moderate or severe reductions in training volume, or moderate or severe reduction in performance, or complete inability to participate in sports.
Recurrent injury	An injury in the same body site as the previous injury within the last year.
Illness	A self-reported health problem other than the musculoskeletal system, such as cold, influenza etc., resulting in reduced training volume or difficulties participating in normal training or competition.

3.4.2 Stress

Although stress is expressed in several ways, Selye defined stress as how the human body respond to noxious stimuli,[148] where a stressor is anything that is perceived as challenging or demanding. High stress levels have been associated with cardiovascular disease, illnesses, anxiety and depression.[149-151] Stress could also be determined based on the degree of life situations that are appraised as stressful. The Perceived Stress Scale (PSS) contains 14 items of general feelings and thoughts about unpredictable and uncontrollable life situations.[141] The scores are obtained using a four-grade Likert-type scale ranging from 0 (never) to 4 (very often), where a total score is determined (range 0-56) by summing the 14 items. Higher scores represent high self-perceived stress levels. However, no cut-off has yet to be proposed. The scale has shown to have good internal reliability and satisfactory construct, concurrent, criterion, and predictive validity.[152, 153]

3.4.3 Nutrition

The Swedish Nutrition Food Agency Index (SNFA Index), previously used in epidemiological studies of the Swedish population, aims to provide an overview of the nutritional quality of a given diet.[142] It comprises 14 items of a diet’s contents, measuring the extent of butter, one’s daily intake of fruits, vegetables, fish, French fries, sausage, sweets etc. The responses from the 14 items are subsequently summarized to provide an index ranging from 0–12, where higher scores represent a healthier diet. The SNFA Index has been shown to be reliable along with demonstrating acceptable criterion validity. In study I, the proportion of athletes who did not meet the national recommended intake of fruit and vegetable (less than once a day) and of fish (less than twice a week) was calculated. Athletes who have reached all three recommendations were also determined. This variable is from here on named Nutrition recommendation.

3.4.4 Self-Esteem

Self-esteem could be defined as an individual general evaluation of one's worthiness as a human being and therefore includes how an individual feel about and value him-/herself.[154] However, no single definition of self-esteem exists and authors define self-esteem differently, which may hamper comparison. Researchers usually consider self-esteem as multidimensional,[155, 156] where unstable self-esteem and contingent self-esteem, such as self-esteem dependent of competence and achievements, are important aspects.[157] For an athlete, a self-esteem dependent on achievements, means that one's self-value has to be consistently earned, for instance, by sport performance results or approval from coaches. That kind of self-esteem fluctuates depending on sport success and is therefore consider fragile, likely affecting general well-being.

The Competence-Based Self-Esteem Scale (CBSE Scale), developed by Johnson & Blom,[143] describe self-esteem as dependent on competence and achievements. The CBSE scale contains 12 items, each ranked on a Likert-type scale from 1 (strongly disagree) to 5 (completely disagree). An athlete with a high competence-based self-esteem score will compensate a low self-esteem by striving for sports success and perfection. In contrary, a non-contingent self-esteem, not based on e.g. success or failure in sports participation, is preferable.[158] The CBSE scale has shown to be reliable and has proven concurrent validity.[143] The result is calculated by taking the average score of all questions.

3.4.5 Sleep

The Karolinska Sleep Questionnaire (KSQ),[140] comprises 18 items, evaluates four aspects of sleep, measured on a 6-point scale; sleep quality, awakening problems, snoring problems, sleepiness as well as average sleep duration during weekdays and weekends. In this thesis only the average amount of sleep during weekdays and weekends were used, since the four sub dimensions of sleep showed limited variation among athletes. Therefore, the proportion of athletes who did not meet the recommendation eight hours or more of sleep per night was calculated for both the weekdays and weekends in study I and IV.[118] The KSQ has, to date, demonstrated good internal consistency and acceptable construct validity for all dimensions.[152]

3.5 ETHICAL CONSIDERATIONS

In study I-IV, athletes were informed verbally and in writing about the purpose, their voluntary participation and right to withdraw from the study at any time. Written consent to participate in this study was collected. Data were collected using online web-based questionnaire (Questback V. 9.9; Questback AS, Oslo, Norway) which is highly secure and credible. The athletes reported directly to the researches, through Questback, without interference by coaches or medical staff, meaning that the injury report could not affect their selection for championships or teams. After the athletes completed their questionnaires, the data were manually downloaded and saved on an external hard drive and was subsequently deleted from Questback. All data were coded to ensure confidentiality and only reported at group level. In accordance with the Swedish Personal Information Act (Personuppgiftslagen), data were presented as group results and no individual results were returned to coaches or Sports Federations. In case of a severe injury or extreme illness, other than musculoskeletal disorders, athletes were told to contact a nearby medical team for assessment. All athletes continued their training and competitions as usual throughout the course of the study. The athletes were allowed to drop-out of the study at any time without explaining the reason for doing this. In study III, athletes were told to only answer questions they found comfortable answering. Ethical approval had been provided for this project (No: 2011/749-31/3, No: 2013/138-321, No: 2015/288-32).

3.6 DATA MANAGMENT

In study IV, multiple imputations were used to handle missing data. A total of five datasets were imputed based on a Chained Equation algorithm[159] in SPSS (V.22, IBM Corporation, New York, USA). The average value of these five datasets was used.[160]

In study IV, pre-event variables of training load, training intensity, sleep volume and number of competition days were determined by taking the value of the week prior to the new injury, relative to the average value of the last four weeks before injury.[116] For athletes reporting no injury, the pre-event variables were calculated by taking the last measure in the dataset relative to the last four or three (if not four values were available) weeks' average measure. From this, new dichotomous variables were created, i.e. the pre-event variables were dichotomized as a factor higher than 1.0 for training load, training intensity, days of competitions and at a factor less than 1.0 for decreased sleep volume, representing the change in training, competition and sleep. In this thesis, these variables are from here onwards named "increased training load", "increased training intensity", "increased number of competition days" and "decreased sleep volume".

In study I, the SNFA index was used as a categorical variable with four levels (score 0-4, 5, 6, 7-12), and in study IV as a dichotomized variable (score ≤ 4 points), based on sample size discrepancies. Sleep duration during weekdays was also used as a dichotomized variable (≤ eight hours). From now onwards these two variables are named "Nutrition Index" and "Sleep weekdays". In study IV, a Risk index was calculated by merging the value of the significant ($p<.05$) risk factors of the dichotomized (coded: 0-1) pre-event variables (increased training load=1, increased training intensity=1, decreased sleep volume=1), to create a categorical variable (0-3). Importantly, a score of zero on the Risk index represents having none of the three risk factors, and a score of three stands for having all three risk factors.

3.7 STASTICAL ANALYSES

Descriptive and inferential statistics were used in this thesis, with specific statistical test summarized in Table 6. The reader is encouraged to consult paper I-IV for further details.

Prevalence measures were calculated for injury, injury consequence variables and illnesses, by dividing the number of athletes reporting any form of injury, injury consequence or illness by the number of questionnaire respondents, at each time point. A similar calculation was performed to determine the response rate, i.e. dividing the responding athletes with the total number of responding athletes, at each time point. The 1-year injury prevalence and 1-year substantial injury prevalence were calculated by dividing the athletes reporting injury and substantial injury for at least one time point over the 1-year surveillance time, by the total number of included athletes for both prevalence indices. The incidence rate of injuries was determined by adding all new injuries per 1000 hours of exposure to sports. The proportional injury incidence was calculated by summing all athletes reporting new injuries each week by the total number of respondents for that week. The 1-year proportional injury incidence was calculated by taking the athletes reporting new injuries during one year and dividing it by the total number of included athletes. Further, the anatomical proportional injury incidence was for each body site determined by dividing the number of new unique injuries in an anatomical area by the total number of new unique injuries. The proportional injury incidence, response rate and all prevalence measures, except for the 1-year prevalence measures were presented as weekly (study II) or bi-weekly (III) averages with its corresponding 95% CI.

Logistic regression and Cox regression techniques were used in study I and IV, respectively, to identify risk factors for injury. The covariates studied were sex, BMI, history of severe injury that affected or completely hindered training for a continuous period of at least three weeks, self-perceived stress,[141] nutrition index,[142] competence-based self-esteem,[143] sleep weekdays (≤ eight hours), increased training load, increased training intensity, increased number of competition days, decreased sleep volume, Risk index, the proportion of athletes reaching the recommended intake of fruits, vegetables, fish, and the proportion of athletes reaching the recommended amount of sleep during weekdays.

All possible risk factors were first assessed using univariate Logistic regression analysis (study I) and univariate Cox regression analysis (study IV). In study IV, a backward stepwise conditional approach was used in the multiple Cox regression analysis, whereas in study I, a forward stepwise procedure was used. Possible risk factors with $p \leq 0.10$ were included in risk factor analyses.[161] The final models were controlled for the influence of sex and age in study I and sex and BMI in study IV.

Table 6. Statistics used in this thesis.

	Study I	Study II	Study III	Study IV
Descriptive statistics				
25th–75th percentiles	•	•		•
Cohen's d effect size measure	•			
Frequency (n), percentage (%)	•	•		•
Kaplan-Meier curve		•		•
Mean	•	•	•	•
Median	•	•		
Min/Max	•	•	•	•
Standard deviation	•	•		•
Inferens				
Cox regression analysis				•
Incidence rate with CI		•		
Injury prevalence with CI		•	•	
Kruskal-Wallis test		•		
Logistics regression analysis	•			
Log-rank test		•		
Mann-Whitney U test	•			
Pearson's chi-square test	•		•	
Proportional injury incidence with CI		•		
T-test	•			

3.8 QUALITATIVE DATA ANALYSIS

Content analysis was used to explore the interview data.[162] The text material was read thoroughly by three of the authors (PvR, AH, AK), two physiotherapist and one occupational therapist, with the aim of the study in mind. The text was then reduced to meaning units, i.e. words and statements relevant to the aim. The selection of meaning units were compared between the three authors and a high level of agreement was found. Using a back and forth ongoing process, the meaning units were then condensed and grouped into subcategories, categories along with a main theme. The analyses were at first performed individually, then circulated between the three authors and finally discussed during meetings in order to reach consensus. This contributed to different perspectives and interpretations, which likely enriched the data analysis.

4 RESULTS

4.1 DATA ON HEALTH VARIABLES

Based on the background questionnaire distributed during the first term, the recommended national guidelines for the intake of fruits, vegetables, and fish intake were not met by 20%, 39%, and 43% of the athletes, respectively. The recommended amount of sleep (more than eight hours of sleep) during weekdays and weekends was not obtained by 18.5% and 1.0% of the athletes, respectively. Female athletes reported significantly higher perceived stress scores (24.7, $p<.001$), competence-based self-esteem scores (2.8, $p<.05$) than male athletes (20.0; 2.6), with a low to medium effect size (Table 7). A significantly ($p<.05$) higher proportion of male athletes (45.4%) did not reach the recommended intake of vegetables, compared to female athletes (32.7%). The perceived stress score was significantly ($p<.05$) higher for athletes aged 18–19 than for 16-year-olds. A significantly ($p<.01$) higher proportion of 16-year-old athletes did not meet the recommendation for vegetables intake (53.4%) compared to athletes of age 18–19 (35.2%).

Table 7. Descriptive data on sleep, nutrition, competence-based self-esteem (CBSE), self-perceived stress (PSS), presented for all athletes, sex and age category. Statistical significance tested for sex and age differences.

	All athletes (n=314)	Male (n=164)	Female (n=150)	Age 16 (n=103)	Age 18–19 (n=108)
Sleep weekdays[a], %	18.5	17.3	19.6	13.9	16.5
Sleep weekends[a], %	1.0	1.8	0	1.0	0
Nutrition Index[b]	5 (4–6)	5 (4-6)	5 (4-6)	5 (4-6)	5 (4-6)
Fruits[c], %	20.1	23.3	16.7	21.4	18.5
Vegetables[c], %	39.3	45.4*	32.7	53.4**	35.2
Fish[c], %	42.5	45.4	39.3	48.5	42.6
CBSE, mean (SD)	2.7 (0.7)	2.6 (0.7)*	2.8 (0.7)	2.6 (0.7)	2.7 (0.7)
		0.13[d]		0.09[d]	
PSS, mean (SD)	22.2 (7.6)	20.0 (7.4)***	24.7 (7.0)	21.0 (7.4)*	23.2 (8.0)
		0.31[d]		0.14[d]	

[a] Athletes not sleeping the recommended amount of sleep (≤ eight hours/day)

[b] Median (25th–75th percentiles)

[c] Athletes not meeting the national recommended intake of fruit, vegetable (less than once a day) or fish (less than twice a week)

[d] Cohen's effect size, calculated on between-group differences

*p < .05

**p < .01

***p < .001

4.2 INJURY PREVALENCE AND INCIDENCE

At the start of the injury registration in year one, 31.0% (n=88) of the athletes were injured. During year one (study II), the 1-year injury prevalence and 1-year substantial injury prevalence were 91.6% (n=260) and 72.2% (n=205), respectively. The average weekly injury prevalence and substantial injury prevalence during year one were 30.8% and 15.4%, respectively, whereas during year two the average biweekly prevalence of injury was 38.7% (95% CI 37.3-40.1) and 18.3% for substantial injury (95% CI 17.3-19.3). In year one, the injury prevalence and substantial injury prevalence decreased with time, whereas the proportional injury incidence remained relatively constant over the study period (Figure 8). During year two (study III), 30.0% (n=102) of the athletes were injured more than half of all reporting times, and 9.7% (n=33) reported substantial injury more than half of all reporting times (Figure 9).

During year one, a total of 326 unique new injuries were identified. The overall injury incidence rate was 4.1/1000 hours exposure to sports, and the 1-year proportional injury incidence was 57.5% (n=163). Of all athletes, 121 athletes (42.6%) reported no new injury, while 80 (28.2%) reported one new injury and 83 (29.2%) reported two or more new injuries during year one (Figure 10).

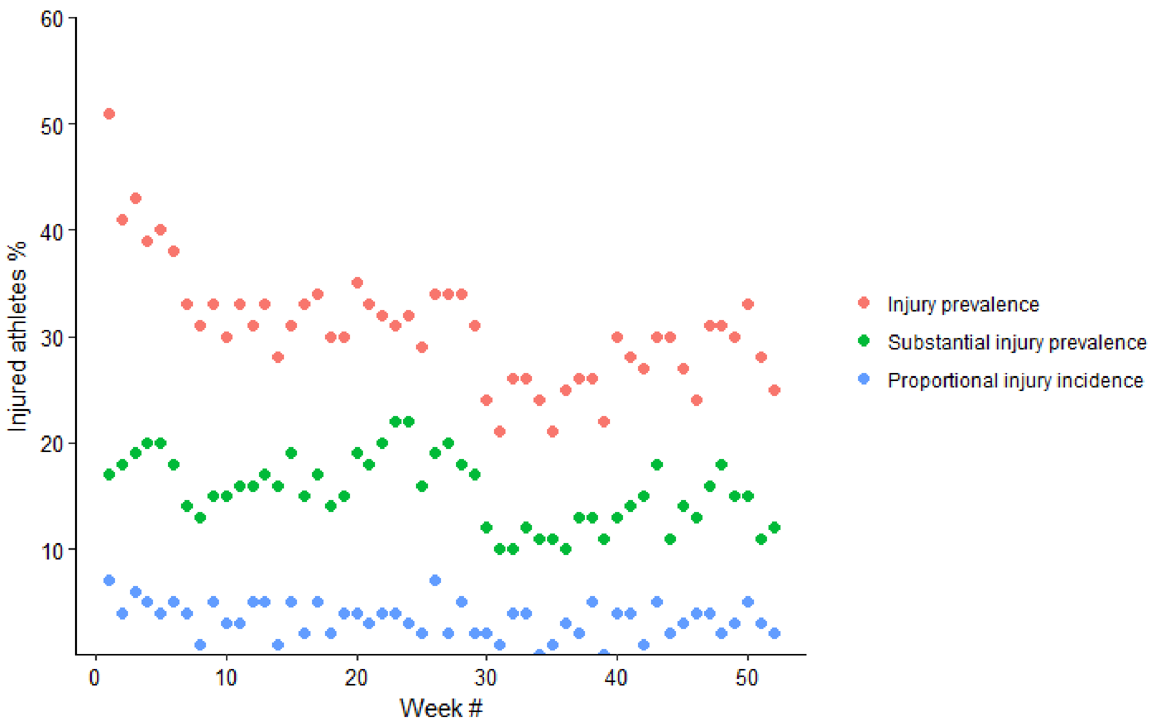


Figure 8. The prevalence (%) of injury and substantial injury and the proportional injury incidence over the 52 weeks in year one.

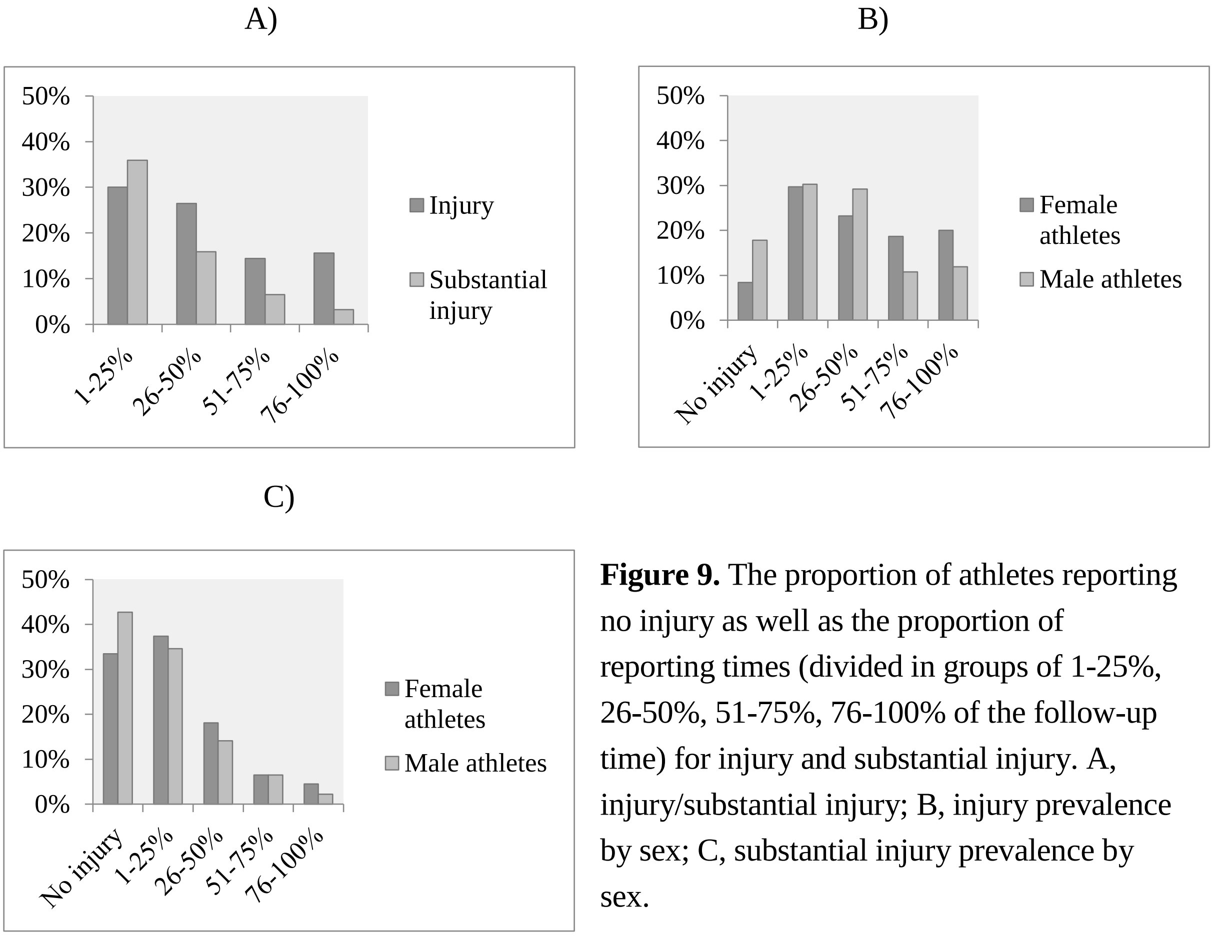


Figure 9. The proportion of athletes reporting no injury as well as the proportion of reporting times (divided in groups of 1-25%, 26-50%, 51-75%, 76-100% of the follow-up time) for injury and substantial injury. A, injury/substantial injury; B, injury prevalence by sex; C, substantial injury prevalence by sex.

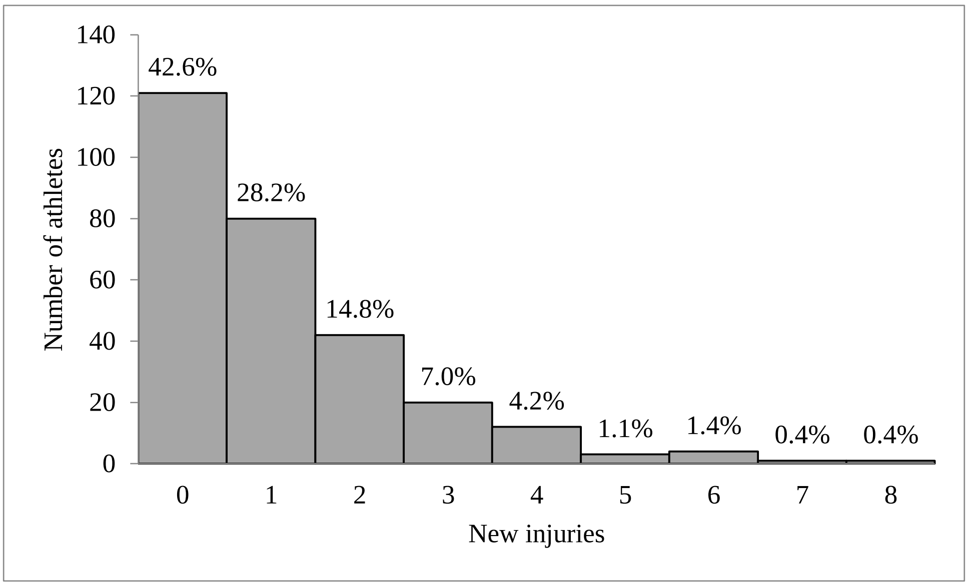


Figure 10. Number of athletes (labels in percent) per number of reported new injuries (0-8).

4.2.1 Sex differences

At the start of the study, a higher proportion of female athletes were injured (36.1%) and reported a history of a severe injury (40.8%) that affected training for a continuous period of three weeks (this was all before entering the study), compared to male athletes (25.5%/31.4%).

Female, compared to male athletes, reported significantly ($p<.05$) higher average weekly injury prevalence (female year one/two, 35.6/43.9%; male year one/two, 25.4/34.5%) and substantial injury prevalence (female year one/two, 17.5/20.6%; male year one/two, 13.0/16.4%), during both year one and two (Table 8, Figure 11). In study III, a higher proportion of female athletes reported longer injury time, of which 38.7% (n=60) were injured more than 50% of the reporting times and 11.0% (n=17) had substantial injury more than 50% of the reporting times, compared to male athletes (injury, 22.7%, n=42; substantial injury, 8.7%, n=16).

The 1-year proportional injury incidence was 55.1% and 59.9% in female and male athletes, respectively. Analogous to this finding, the average proportional injury incidence was similar for male (3.5%, 95% CI 3.2-3.8) and female athletes (3.2%, 95% CI 2.9-3.5).

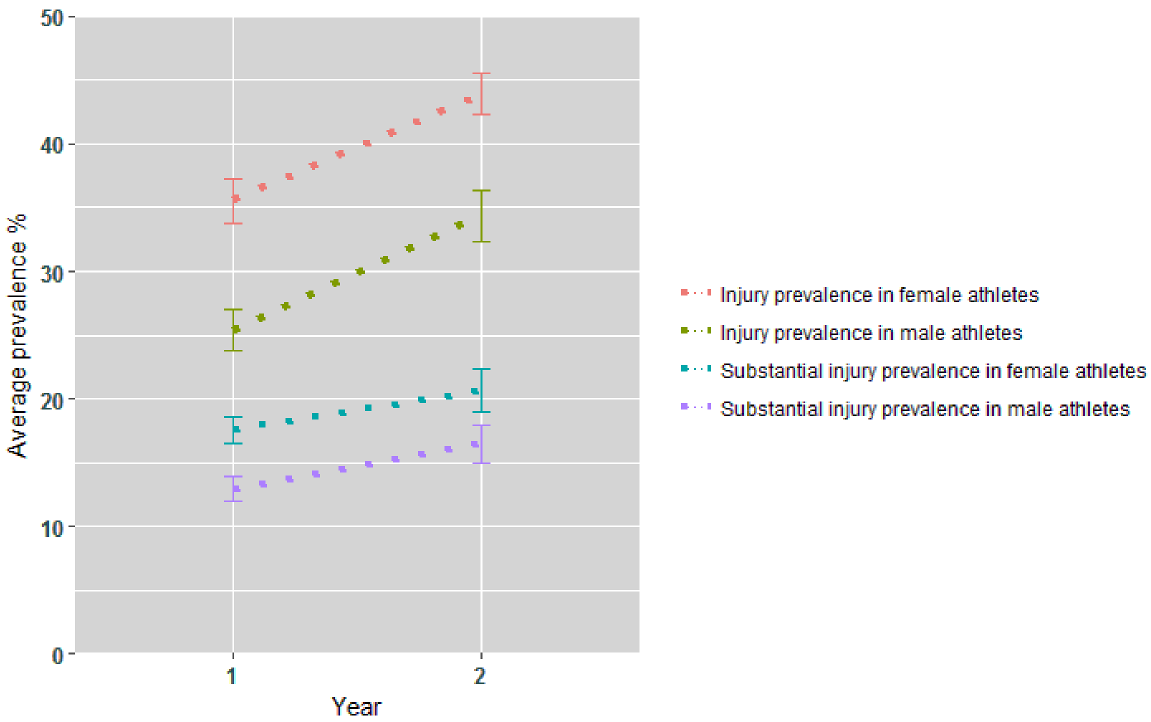


Figure 11. Average weekly injury prevalence/substantial prevalence during year one and the average bi-weekly injury prevalence/substantial prevalence during year two, by sex. Error bar: 95% CI.

4.2.2 Sports types

Of all sporting types, Handball players had a significantly highest average weekly injury prevalence ($p<.001$; 47.2, 95% CI 45.7-48.7) and substantial injury prevalence ($p<.001$; 28.6, 95% CI 27.6-29.6). Endurance running and Endurance skiing athletes reported the lowest average weekly injury prevalence (Endurance running, 19.4, 95% CI 18.3-20.5; Endurance skiing, 21.4, 95% CI 20.4-22.4). Power (34.7, 95% CI 33.1-36.3) and Sprint athletes (32.6, 95% CI 31.1-34.1) were ranked between Endurance athletes and Handball players, in terms of injury prevalence. For more injury data on sports types, please see paper II.

Table 8. The average weekly (year one) and bi-weekly (year two) prevalence of injury in percent, for all athletes and by sex, with 95% CI in parenthesis.

	Year one			Year two		
	All athletes (n=284)	Female (n=147)	Male (n=137)	All athletes (n=340)	Female (n=155)	Male (n=185)
Injury prevalence	30.8 (30.0-31.6)	35.6 (34.7-36.5)	25.4 (24.6-26.2)	38.7 (37.3-40.1)	43.9 (42.3-45.5)	34.5 (32.5-36.4)
Substantial injury prevalence	15.4 (15.0-15.8)	17.5 (17.0-18.0)	13.0 (12.5-13.5)	18.3 (17.3-19.3)	20.6 (19.0-22.3)	16.4 (14.9-17.8)
Difficulties participating in normal training or competition due to injury	19.9 (19.3-20.5)	22.9 (22.3-23.5)	16.4 (15.8-17.0)	25.2 (24.2-26.2)	26.6 (24.9-28.3)	24.1 (22.7-25.6)
Reduced training volume due to injury	15.9 (15.4-16.4)	18.1 (17.5-18.7)	13.4 (12.9-13.9)	17.7 (16.3-19.0)	18.8 (16.5-21.0)	16.8 (15.5-18.0)
Reduction in performance due to injury	19.0 (18.4-19.6)	22.5 (21.8-23.2)	14.9 (14.3-15.5)	24.3 (23.5-25.1)	26.8 (25.7-27.9)	22.3 (20.8-23.9)
Experience of pain due to injury	25.1 (24.4-25.8)	29.6 (28.6-30.6)	19.9 (19.2-20.6)	34.3 (32.9-35.6)	38.9 (37.2-40.6)	30.6 (28.5-32.6)

4.3 INJURY LOCATIONS AND SEVERITY GRADE OF INJURIES

Based on the data collected during year one, the majority of injuries occurred in the lower extremity (69.2%, n=226), defined as all body parts from the hip to toes. The highest anatomical proportional injury incidence occurred in the foot (24.5%, n=80), followed by knee 15.6% (n=51) and lower back 11.7% (n=38). Of all injuries, 48.4% (n=158) recovered during the study period. Of the reported recovered injuries, 37.4% (n=59) resulted in absence from normal training for more than four weeks and 10.8% (n=17) for more than six months (Table 9). Based on injury registration data for year one, knee injuries caused the greatest severity grade among all athletes (3.76), followed by the foot (2.50) and lower back (1.67).

Table 9. Number of injuries per injury type, injury situation, injury onset and severity type, presented for all athletes and by sex.

	All athletes	Female athletes	Male athletes
Overall injury data			
Injury	326	168	158
Injury type			
Recurrent injury[a]	92 (28.2)	44 (26.2)	48 (30.4)
Non-recurrent injury	234 (71.8)	124 (73.8)	110 (69.6)
Injury situation			
Training	250 (76.7)	135 (80.4)	115 (72.8)
Competition	76 (23.3)	33 (19.6)	43 (27.2)
Injury onset			
Gradual	132 (40.5)	73 (43.5)	59 (37.3)
Sudden	194 (59.5)	95 (56.5)	99 (62.7)
Severity[b]			
Minor	40 (25.3)	20 (21.1)	20 (31.7)
Moderately serious	59 (37.3)	33 (34.7)	26 (41.2)
Serious	42 (26.6)	28 (29.5)	14 (22.2)
Long-term	17 (10.8)	14 (14.7)	3 (4.8)

[a] An injury in the same body site as the previous injury within the last year

[b] Minor, 1–7 days absence from normal training; Moderately serious, 1 to 4 weeks absence from normal training; Serious >28 days–6 months absence from normal training; Long-term >6 months absence from normal training[147]

4.4 TIME TO FIRST REPORTED INJURY

The median time to first reported injury was 20 weeks (95% CI 12.5-27.5). Handball players had the significantly ($p<.001$) shortest time to first reported injury (9 weeks, 95% CI 6.4-11.6), compared to other sports types. No statistically significant ($p=.336$) difference was found between male (20 weeks, 95% CI 11.1-28.9) and female athletes (20 weeks, 95% CI 4.5-35.5).

4.5 PREVALENCE OF ILLNESS

The average prevalence of illness for all athletes was 12.1% (95% CI 11.6-12.6), and no significant difference was observed between female (12.4%, 95% CI 11.7-13.1) and male athletes (11.9%, 95% CI 11.3-12.5).

4.6 RISK FACTORS FOR INJURY

Risk factors identified in univariate analysis and multiple Logistic regression/Cox regression are presented in Table 10 and Table 11. In the multiple Logistic models, athletes not reaching the sleep recommendation during weekdays had 2.56 times increased odds of injury (95% CI, 1.01-6.45), whereas athletes not meeting the recommended nutrition intake had 2.78 times increased odds of injury (95% CI, 1.10-7.02), after adjusting for sex and age.

Table 10. Univariate Logistic regression and Cox regression analyses of risk factors to first reported injury.

Baseline measures	HR (95% CI)	p value	OR (95% CI)	p value
Sex (male reference)	1.04 (0.79-1.36)	0.802		
BMI	1.01 (0.95-1.07)	0.813		
History of severe injury	1.15 (0.86-1.54)	0.338		
Nutrition Index				
score ≤ 4 points	1.31 (0.99-1.74)	0.059		
Nutrition Index				
score 0-4			Reference	0.724
score 5			0.48 (0.12-1.97)	0.306
score 6			0.53 (0.13-2.12)	0.371
score 7-12			0.70 (0.17-2.91)	0.620
Nutrition recommendation[a]			2.66 (1.11-6.39)	0.028
Sleep weekdays (≤ 8 hours/day)	1.32 (0.98-1.78)	0.064	2.45 (1.04-5.79)	0.041
Competence-based self-esteem	1.02 (1. 003-1.04)	0.018	1.02 (0.97-1.07)	0.526
Self-perceived stress	1.02 (0.99-1.04)	0.088	0.98 (0.93-1.04)	0.552
Pre-event variables				
Increased training intensity	1.37 (1.05-1.80)	0.021		
Increased training load	1.40 (1.07-1.82)	0.015		
Increased competitions days	1.24 (0.91-1.69)	0.172		
Decreased sleep volume	1.46 (1.10-1.94)	0.008		
Risk Index[b]				
One risk factor	1.18 (0.82-1.69)	0.378		
Two risk factors	1.35 (0.95-1.93)	0.092		
Three risk factors	2.37 (1.55-3.61)	<0.001		

CI, confidence interval; OR, odds ratio; HR, hazard ratio

[a]Not meeting the national recommended intake of fruit and vegetable (less than once a day) and of fish (less than twice a week)

[b]Reference, no risk factor

Table 11. Multiple Logistic regression and Cox regression analyses of risk factors to first reported injury.

Model	OR (95% CI)	p value
Model I[a]		
Sleep weekdays (≤ 8 hours/day)	2.56 (1.01-6.45)	0.047
Nutrition recommendation[b]	2.78 (1.10-7.02)	0.030
	HR (95% CI)	p value
Model II[c]		
Nutrition Index	1.32 (0.99-1.76)	0.060
Competence-based self-esteem	1.02 (1.003-1.04)	0.020
Sleep weekdays (≤ 8 hours/day)	1.31 (0.97-1.78)	0.080
Increased training load	1.36 (1.03-1.79)	0.028
Decreased sleep volume	1.42 (1.06-1.89)	0.018
Model III[c]		
Nutrition Index	1.31 (0.98-1.75)	0.066
Competence-based self-esteem	1.02 (1.004-1.04)	0.017
Risk Index[d]		
One risk factor	1.17 (0.81-1.69)	0.404
Two risk factors	1.32 (0.93-1.89)	0.125
Three risk factors	2.25 (1.46-3.45)	<0.001

CI, confidence interval; OR, odds ratio; HR, hazard ratio

[a] Adjusted for sex, age category

[b] Not meeting the national recommended intake of fruit and vegetable (less than once a day) and of fish (less than twice a week)

[c] Adjusted for sex, BMI

[d] Reference, no risk factor

Based on multiple Cox regression analyses on repeated measured data, two models were developed. In Model II, an increase by one point on the competence-based self-esteem instrument increased the hazard of injury with 1.02 (95% CI 1.003-1.04), p=0.02), whereas an unhealthier diet increased the hazard of injury with 1.32 (95% CI 0.99-1.76, p=0.06) compared to following a healthier diet. Further on, sleeping ≤ eight hours increased the hazard of injury with 1.31 (95% 0.97-1.78, p=0.08) compared to sleeping more than eight hours, and finally, increasing the training load and decreasing the sleep volume were associated with increased hazard of injury with 1.36 (95% CI 1.03-1.79, p=.03) and 1.42 (96% CI, 1.06-1.89, p=.02), respectively. In Model III, one point on the competence-based self-esteem instrument increased the hazard of injury with 1.02 (95% CI 1.004-1.04), p=0.01), an unhealthier diet increased the hazard of injury by 1.31 (95% CI 0.98-1.75, p=0.07), and increasing the training load, training intensity, while decreasing the sleep volume at the same time, increased the hazard of injury by 2.25 (95% CI, 1.46-3.45), compared to no change in these variables.

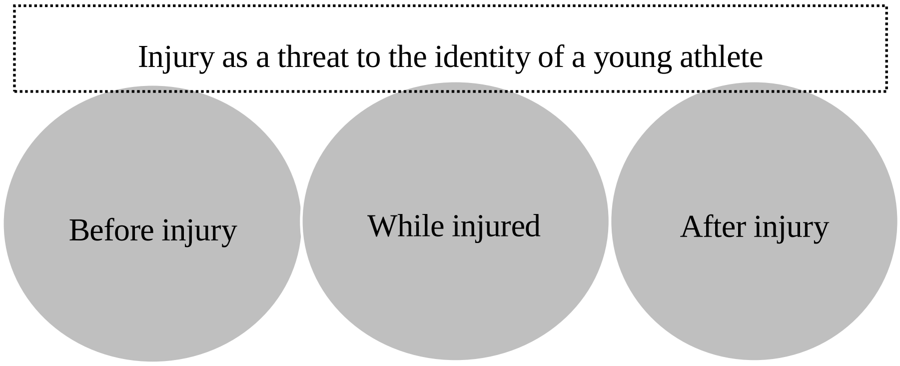
Based on Model III, an athlete having the significant (p<.05) risk factors (Risk Index, competence-based self-esteem), with an average competence-based self-esteem score of 32, had more than a threefold increased risk for injury (HR: 3.35), compared to an athlete with a low competence-based self-esteem (score 12) and no change in sleep or training volume.

4.7 INJURY AS A THREAT TO THE IDENTITY OF A YOUNG ATHLETE

A total of three categories and 15 subcategories were derived from the analysis of the interviews (Figure 12). An overarching theme, "Injury as a threat to the identity of a young athlete", was identified and three interrelated themes emerged from the data: *1. Personal and environmental factors influencing the recovery process, 2. Experiences and lessons learned from injury, 3. Questioning the life-role as an elite athlete*. The results are illustrated by quotes. For a more comprehensive description of results, please see attached study III.

4.7.1 Factors influencing the recovery process

The athletes identified several different kinds of factors that were influencing their recovery process while injured, such as identifying the injury cause or having an injury diagnosis. They also described and stressed the importance of social support from friends, family and coaches. In addition, various coping strategies were used, such as accepting the injury or focusing on the positive aspects of being injured (e.g. increased motivation to return to sports).



Subcategory	Subcategory	Subcategory
• Athletic identity	• Loneliness • Self-blame • Negative psychological responses • Rehabilitation discrepancy/setbacks • Identifying injury cause/diagnosis • Coping • Social support • Effect on personal life • Perceptions by friends • Future concerns	• Goal-setting change • Change pain perception • Developing psychological skills • Prevention skills

Figure 12. Subcategories arranged according to injury time with the overarching theme.

Some athletes experienced that their rehabilitation was not adjusted according to their individual requirements. They expressed starting the rehabilitation with low-dose exercises was a difficult transition, instead of continuing with elite sports. One of the female participants described:

"*During my rehabilitation, I had to sit with a stick on the floor and do arm-lifts. We usually do strength training, and it was very tough because I just sat with a stick and did arm-lifts. Ah, it felt ... it was mentally tough, and I felt extremely weak, just because I sat with a stick.*"

Being injured was also expressed by participants as leading to a variety of negative consequences, such as having fear of movement and feeling depressed. But also several physical symptoms were described as consequences (e.g., loss of appetite, sleep disturbances, educational issues). This was expressed by one of the female participants:

"*I have sleep problems. Since I cannot run…I am not tired at night. Even if I am training, I am not working out as usual. Therefore I have difficulties with my sleep*."

4.7.2 Experiences and lessons learned from injury

The experience of injury led to increased knowledge and the development of prevention skills, but also increased motivation, improved self-confidence and mental health. Increased motivation following injury is illustrated by the following quote from a male participant:

"*I am more motivated due to my injury. I want to run again and perform at maximum effort at the next training session. I cannot wait*."

Some athletes expressed gratitude for being injured and were thankful for the experiences they gained during this period. They also described that they were prompted to revise their short-term goals (seasonal) after injury, by starting to consider the avoidance of injury as a short-term goal, while keeping on track with their consistent long-term goals (career).

Following the injury period, some participants described a change in the perception of pain. Before injury, pain was a natural part associated with normal sports participation and not with injury. As expressed by one of the female participants:

"*It started when I started doing intensive training. But then I did not think that there was something wrong with experiencing pain. After a few years I realized that it was not normal to feel pain during sports."*

After injury the athletes expressed an increased awareness to injury threats and increased awareness to signals of pain and the recovery level. As illustrated by one of the female participants:

"I have started to listen to my body more. Because it is how injuries can be avoided."

4.7.3 Injury as a threat to the identity of a young athlete

When athletes are withdrawn from their regular sports' involvements due to injury, injury may act as a great threat to the identity of an athlete. This is illustrated by the following citation from a female participant:

"*It's who I am. I am an athlete, it's the first thing I say. If that is not the case, then what?*"

The close relationship between being identified as injured by others and identity, is illustrated by the following citation from a female participant:

"*After being injured for several years now, I have started to blame myself because I'm so clumsy. I think everybody saw me as clumsy. And my coaches began to make jokes about it and just said you cannot even play football because you will sprain your ankle. I was not feeling alright*."

While injured, some athletes described they felt lonely and excluded from regular sports' involvement. They also expressed they miss being part of a sporting group, as well as receiving attention and admiration from friends or coaches which they were commonly used to. This resulted in athletes, as experienced by some for the first time, starting to question their reasons for continuing with elite sports.

In addition, the athletes described that they wanted to be recognized and acknowledged by their friends as not just "the injured" athlete. This was expressed by one of the female athletes:

"*Everybody should see the ones who are injured. See them. Talk to them. Acknowledge their training. And try to talk to them about something other than their injury."*

5 DISCUSSION

Due to the high number of athletes studying at Swedish National Sports High Schools, in the light of limited number of injury registration studies conducted in this population, the overall aim of this thesis was to explore injury patterns, health variables, and risk factors for sustaining a sport injury. Since data are lacking on the consequences of sports injuries in young elite athletes, this thesis also aimed to explore athletes' perceptions and experience of being injured.

The main finding was the high injury burden in this population. On average, more than three out of ten athletes were injured each week. The consequences of injury affected sport participation, training volume, performance and pain perception. In addition, about 30% (n=102) of participating athletes were injured for more than half of all reporting times during year two. Several risk factors for injury were identified, which could be used to predict injury risk. An increase in training volume, training intensity, while decreasing the sleep volume, resulted in a higher risk for injury compared to no change in these variables. In addition, an increase in competence-based self-esteem increased the risk for injury. The interview data identified an overarching theme, illustrating that young athletes may experience a loss of identity while injured. Besides, athletes also described a sense of being excluded while injured, which may affect their rehabilitation as well as their return to sports following injury.

5.1 HIGH INJURY BURDEN

Comparing injury data among studies is challenging due to the use of different injury definitions or study designs.[45] For instance, the commonly used injury definition (time loss) is easy to apply in sports settings, but will mostly identify injuries associated with the highest severity. Besides, elite athletes often continue with sports participation even if injured or perceiving pain, leading to that the time-loss definition may accurately account for only a small part of all injuries.[89] Instead, other injury definitions capturing injuries causing mild and moderate symptoms as well may more correctly identify the injury burden.

Based on the results from the injury registration of year one and two, it is clear that adolescent elite athletes are exposed to high injury risk, with a certain amount of athletes injured for a longer duration of the season. A similar average weekly and biweekly prevalence of injury and substantial injury were found during both years, even if the injury prevalence was slightly higher during year two (39%/18% vs. 31%/15%). A similar pattern was observed for the injury consequence variables (injury affecting participation in sports, performance, training and pain perception). For instance, during year one, on average 25% experienced pain, whereas during year two 34% experienced pain. The difference may be explained by different sampling frequencies, even if a study has demonstrated that as a non-contributing factor.[89] It could also be related to the inclusion of different sports. For instance, a handball player will likely not have the same injury risk as a triathlete due to different training exposure, competition season, biomechanical loading etc., leading to that the injury data from year one and two are difficult to compare. However, our finding of a high injury burden in this population, is in line with epidemiological data on similar populations,[6, 80, 163] supporting the need to further analyzing the consequences of these injuries. By following athletes during a complete season, the potential variation in injury prevalence over the entire season is likely covered.

Over year one and two, female athletes reported a higher average injury and substantial injury prevalence. In addition, a higher proportion of injuries leading to more serious consequences on, for example, sports participation or performance were reported in female athletes, compared to males. The difference between sexes concerning injury prevalence data could be related to the fact that more female athletes were injured at the start of the study (36% vs 26%), and were therefore more likely to continue reporting injury. Furthermore, a higher proportion of female athletes had a history of a severe injury (within one year before entering the study), which could be related to increased injury risk.[49, 105, 106, 164, 165]

An interesting finding occurring over the first year was that 43% of the athletes reported no new injury, whereas only 8% reported no prevalence of injury at any given time. This finding illustrates that almost all athletes are likely to be injured, at least at one time point. Since injury incidence does not account for injuries at the start of this study, the difference between these measures are likely related to injuries occurring before or at the start of the injury surveillance.[45, 89]

5.2 ARE THE INJURIES OF SEVERE NATURE?

Different kind of severity measures have been used in this thesis, such as the severity grade and time absent from normal training. The severity grade can be described as a measure of the consequences of injuries on sports participation, training, performance and pain, adjusted for different group sizes and response rates in each sport.[89] Measuring time absent from normal training is related to the time loss definition. However, the definitions differ since time absent from normal training definition only requires alterations in normal training, instead of complete absence from sports (time-loss definition).

More than a third of all new injuries (37%) resulted in absence from normal training for at least four weeks. However, only 48% (n=158) of these injuries were recovered during the study period, indicating that the remaining injuries did not fully recover during the study, or were lost to follow-up. Even if all the remaining injuries would have led to less than 7 days absence from normal training, 18% of all injuries would still result in more than four weeks absence from normal training. Consequently, based on this measure, a considerable proportion of all injuries sustained in adolescent elite athletes are leading to long-term consequences on sports participation.

Based on the seven sports studied during year one, knee and foot injuries caused the greatest severity grade among all athletes, as well as male and female athletes. This is in agreement with numerous reports,[49, 80-82, 85, 88] indicating that preventive measures focusing on knee and foot injuries will address the majority and the predominant injuries with serious consequences, in young elite athletes.

Female athletes reported a higher proportion of injuries resulting in absence from normal training for at least one month (n=42, 44%), compared to males (n=17, 27%). Knee injuries led to a higher severity grade in female athletes, compared to males, whereas foot injuries caused higher severity grade in male athletes. The fact that female athletes have a higher risk for knee injuries in general,[163] including serious knee injuries such as ACL injury, have been previously reported.[11, 166] Several contributing factors, such as early sports specialisation, anatomical alignment, diet, sleep, stress, have been suggested to explain the higher risk of knee injuries in female athletes.[167] Interestingly, a higher proportion of female athletes reported longer time with injury compared to males. However, this difference was not as pronounced for substantial injury, possibly illustrating different reporting threshold of injury between the sexes.

5.3 RISK FACTORS FOR INJURY

This is not the first study that have targeted injury risk factors using multiple variables in young elite athletes, but is however one of the first studies that has used a biopsychosocial approach in assessing risk factors for injury in adolescent elite athletes. However, two different study designs were used to explore injury risk. In study I, risk factors for first reported injury were explored based on two time points, whereas in study IV repeated measured data (weekly/biweekly) during year one and two were used. By including more time points and accounting for the time to first reported event (injury), the statistical power is greater in study IV compared to study I, where the exposure time was assumed to be similar for each athlete. Besides, instead of focusing on absolute values, the strength of repeated measured data is the possibility to monitor changes in variables before an event had occurred. A risk factor of the baseline measures may render the athlete susceptible to injury while the occurrence of pre-event variables may increase the risk of injury even further, similar to the multifactorial model by Meeuwisse.[101, 102]

The risk factor analyses clearly show that no single risk factor provides an adequate etiological explanation of injury. Instead, by combining risk factors, a higher risk of injury was identified compared to the presence of a single risk factor. This confirms that the cause of injury is multifaceted, involving risk factors which interact in complex ways.[102, 168] Meeuwisse et al.[101] argued, already in the 1990's, for the use of a multifactorial approach in understanding injury causality. However, few studies have yet adopted such an approach, which makes it difficult to fully understand injury risk, since controlling for multiple risk factors may not be possible.

Based on a biopsychosocial framework the risk of injury was explored based on multiple risk factors (Figure 13). This led to the identification of the Risk Index, reflecting that the injury risk increased along with an increase in training load and intensity while decreasing volume of sleep. The Risk Index could simulate a training camp situation, where the training load is likely increased at the same time as the sleep pattern or volume may be disturbed. It may further reflect the balance between training load and rest, which as a result, increase stress on the musculoskeletal system, causing fatigue, functional impairments, illness and possibly injury occurrence.[169, 170] In study IV, it was found that the competence-based self-esteem acted as a risk factor for injury. The athlete with a high competence-based self-esteem may engage in risk situations, have a negative pattern of perfectionism associated with anxiety,[171] and not knowing how to successfully deal with issues and setbacks or criticism, possibly leading to an increased injury risk. The identified risk factors are modifiable, meaning that an athlete can change the risk associated with the risk factor, for instance by improving their self-esteem or not increasing their training intensity and load at the same time. However, modifying a specific risk factor and its subsequent effect on injury risk per se has not been explored in this thesis. Addressing athletes with a high competence-based self-esteem may also be a way of identifying athletes with increased injury risk at pre-season.

The Nutrition Index and Sleep weekdays were two variables that were almost statistically significance in the multiple Cox regression models. Both these variables are believed to affect ones recovery level.[172, 173] For instance, sleep deprivation is associated with reduced reaction times, performance, motivation, mood changes[170, 174-176] and increased injury risk in adolescent athletes,[126] and for stress fractures in the military.[177] An unhealthy diet, reduced recovery between training sessions and competitions,[121] increased the risk of eating disorders,[127] which in female athletes has been found to impair bone mass, lead to menstrual dysfunction and increased risk of injuries such as stress fractures.[122] Besides, the finding of study I that not all athletes meet diet recommendations is consistent with previous studies.[178, 179]

Self-perceived stress was not identified as a risk factor in this study, probably because this variable was only measured at baseline. Several reports have shown self-perceived stress or daily hassles to increase the injury risk in sports[131, 133, 180, 181] and in military personnel.[182] However, due to variability in stress over time, often related to unpredictable and uncontrollable life events, is likely to be a better predictor of injury if measured repeatedly over a season.

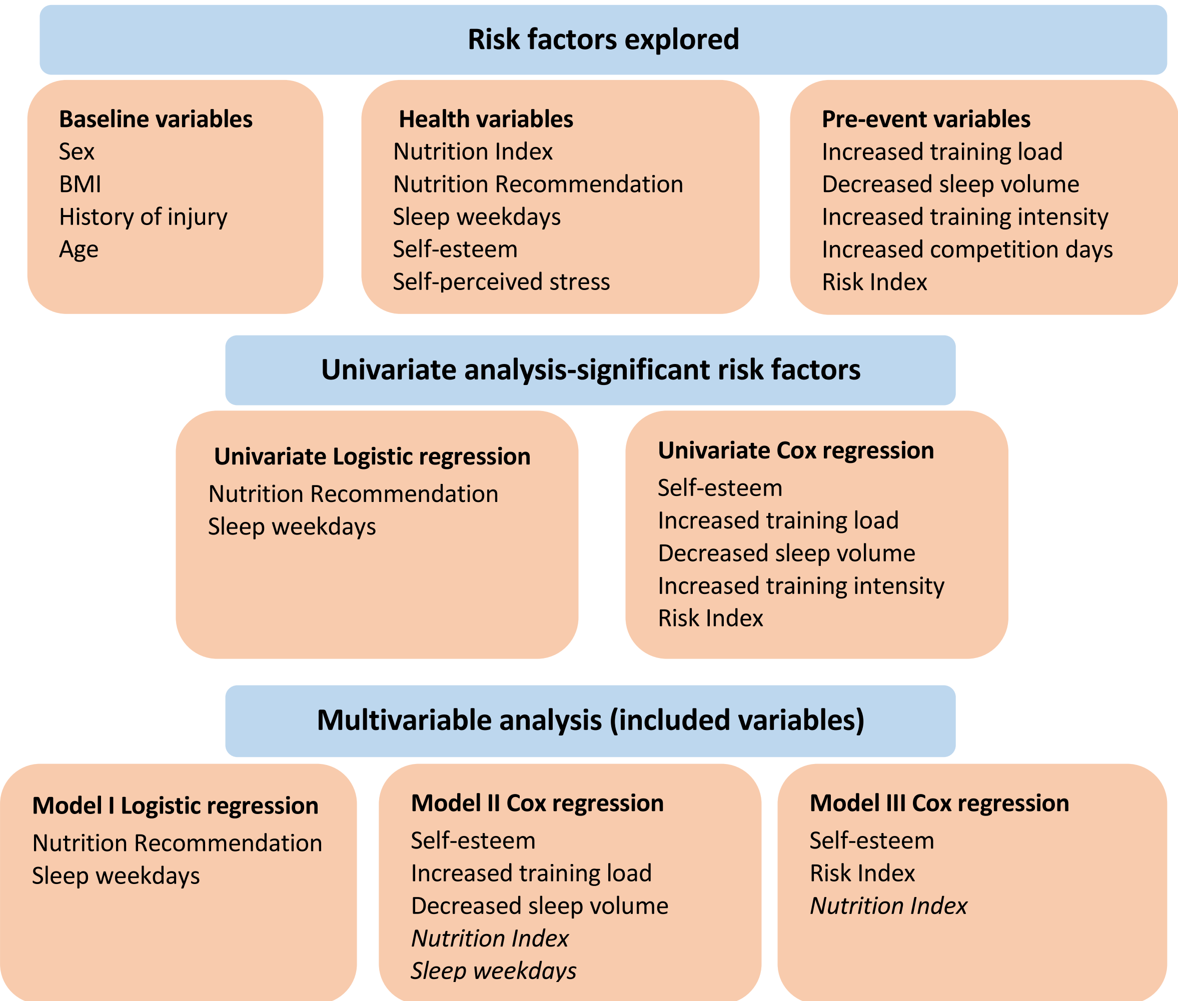


Figure 13. Illustrating the studied risk factors, the significant risk factors based on univariate analysis and the final variables included in the multivariable models. Italics indicate a non-significant (0.05> p <0.10) risk factor. Self-esteem, competence-based self-esteem; Risk Index, increased training load, increased training intensity, decreased sleep volume.

5.4 INJURY CONSEQUENCES

Besides causing physical symptoms, such as pain or tissue swelling, it is well known that sport injuries may also lead to psychological symptoms like, for example fear, disbelief, tension and low self-esteem, which have not been well explored in adolescent elite athletes.[90, 93, 183-186] In study II and III, the consequences of injuries on sports participation, training volume, performance and injury perception were studied. In study III, a more in-depth perspective, using interview data, on injury consequences was explored, including both physical and psychological effects of injury.

The findings show that injuries have a great impact on sport participation and performance, and cause both physical (sleep disturbance, less appetite, functional limitation) and psychological symptoms (feeling pressured, clumsy, depressed, physically limited, fear of movement, lack of motivation etc.), in this young population (Figure 14). In addition, it was found that the self-identity of athletes in this age group may be highly associated with sport participation and performance. While injured, these athletes expressed and questioned their own self-identity and lost track of their own identity,[187, 188] which in the end may contribute to their questioning of whether elite sports was suitable for them. The fact that athletes' self-identity is under threat while injured or when sports participation is threatened, has previously been found in adult elite athletes.[189-191] However, young athletes have likely less experience with being injured as compared to adult athletes, while some of the athletes who were interviewed had not even experienced their first injury or never had a severe injury before studying at National Sports High Schools. Therefore, it is not difficult to imagine that injury has such a tremendous impact and severe consequences in this age group.

Adolescent elite athletes without ever experiencing injury may expect to participate and compete in sports all year, without much thought or fear of getting injured. This is problematic due to the great transition in function, activity or social life an athlete has while being injured, which young athletes may not be prepared for. Without previous injury experience an athlete's rehabilitation expectations and their ideal time to return to sports following injury may not be realistic. By letting previously injured athletes share their experience with young athletes with no injury history, may cause them to be more prepared to handle the consequences of injury at the time of their first injury. Since our results indicate that most athletes at National Sports High Schools will likely be injured at least once a year, strategies are needed to help prepare athletes to handle injuries. Besides, since sports seem to constitute such an important social component of a young athlete, everything that is threatening sport participation is likely to have a major impact on the life of a young athlete. Therefore, by preparing young athletes to handle set-backs associated with sports participation, athletes may be better at handling psychological aspects which accompany injury.

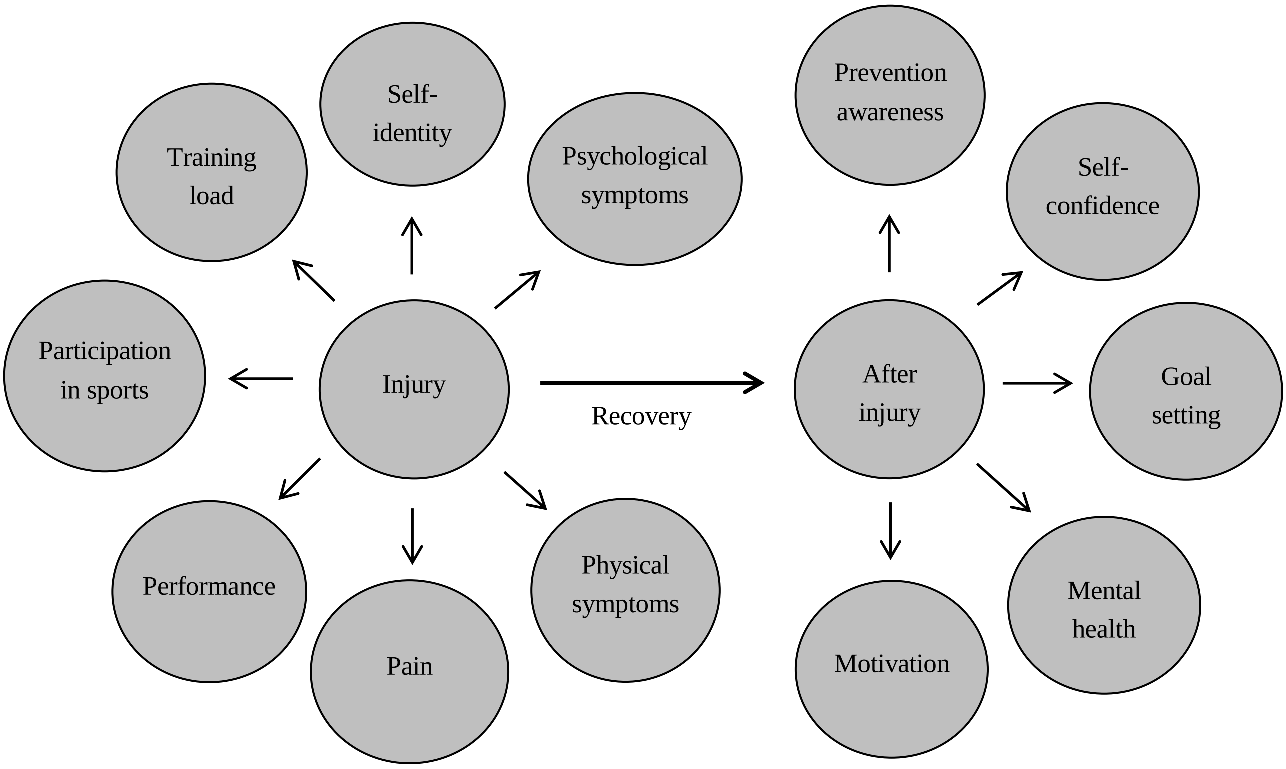


Figure 14. Multiple consequences for a young athlete while injured and following injury.

5.5 METHODOLOGICAL CONSIDERATIONS

Several methodological considerations that may influence the interpretation of the results should be considered. These concerns address to what degree the results can be extended to a certain population or context (external validity), and the extent to which the findings of a study are accurate and representative for the entire study sample (internal validity).

5.5.1 External validity

The study samples consisted of adolescent elite athletes from 24 Swedish National Sports High Schools, 16 different sports and finally included approximately 57% of all adolescent elite athletes available. The main reason why not more sports were included was mainly related to the high number of National Sports Federations which were already involved in other types of injury registration projects and therefore rejected their participation in this study. However, a respectable number of the total available cohort of adolescent elite athletes in Sweden has been studied in at least one of the four studies. Of these, most of the athletes who were followed were individual athletes apart from two team sports that were monitored (handball, American football). Therefore, the results of this study are believed to extent to mainly individual adolescent elite athletes, given that team sports may have different sports' conditions and thereby injury risks, i.e. not all athletes may be selected to games, irrespective of injury status.

Still, there may be limitations affecting the generalisability of our findings. For the athletes that declined participation (n=52) and did not enter any of the four studies at any given time, very little is known about their reasons to decline. This might have led to a selection bias, for instance if mainly the healthy athletes were included. In order to continue participating in weekly or bi-weekly injury registration over a period of one to two years, high motivation levels and personal commitment is likely needed, which may affect who is willing to participate fully during such a lengthy project. Still, we do not know for sure if the athletes that decided to stop returning their injury questionnaire was due to injury, illness, motivation or less involvement in sport participation. The exclusion analysis showed no systematic difference between the main cohort and excluded athletes with respect to sex and sports participation (study II), sex (study III), and injury history (study IV). However, a higher proportion of the excluded athletes were participating in athletics (study IV), which suggest that other factors may be responsible for explaining the drop-out rates. When contacting athletes who have dropped out, some claimed they stopped with the injury registration due to them having ended studying at National Sports High Schools or stopped with sport involvement. The majority of drop-outs provided no explanations. Some drop-outs were also related to not receiving emails or issues with accessing the email service. Finally, by presenting data for all athletes, irrespective of sports disciplines, may reduce the generalisability to specific sports. Follow-up studies on specific sports are therefore planned.

5.5.2 Internal validity

The injury registration questionnaire has previously been found valid and reliable,[89, 145] but it is not known how suited it is for younger athletes. In Jacobsson et al.,[49] 17 years old athletic athletes were monitored using a similar questionnaire as in this thesis and in von Rosen et al.,[50] a modified version of the injury questionnaire was distributed to a cohort of adolescent elite orienteerers. Both studies showed that the questionnaire was interpreted satisfactory by the young athletes. However, it has not been validated in this specific cohort. The choice of sampling frequencies of the questionnaire is complicated. By having a long time between questionnaire distributions, important injury data may not be collected, whereas by having too little time between questionnaire distributions may result in increased demands on athletes, leading to a potentially low response rate. In this thesis, a similar response rate was found between weekly and bi-weekly questionnaire distribution.

However, the fact that some of the athletes were monitored during year one as well as year two may have led to a decrease in response rate in year two. Therefore, it is believed that a higher response rate would occur following a bi-weekly sampling frequency, compared to a weekly sampling frequency.

The injury prevalence was reduced over time during year one, indicating that respondent fatigue may have occurred. Respondent fatigue means that athletes are less likely to report minor injuries, due to increased reporting threshold. This has previously been demonstrated in longitudinal studies.[50, 89] What is not clear however is whether respondent fatigue is related to the time period that athletes are followed or the individual number of questionnaires returned, or a combination of these. The substantial injury and proportional injury incidence was rather constant during the study course, implicating these values to be valid for the study sample, whereas the injury prevalence may be underestimated due to respondent fatigue.

Multiple actions were taken to enhance an adequate response rate, such as visiting the schools yearly, regular contact with coaches, e-mail reminders, as well as arranging competitions between schools in terms of highest response rate. The schools participating in year one were also given injury reports of their athletes (on a group level) after the end of year one. This was done to enhance the response rate. Nevertheless, the response rate was not high in both year one or two when compared to 78-95% found in previous studies,[49, 50, 84, 89, 192] but in line with 63% as found in Clarsen et al.[193] Since, no reference values exist, along with only a few studies that have monitored this group of athletes repeatedly for one to two years, it is difficult to ascertain what a satisfactory response rate might be. The response rate was also likely reduced following the graduation of final year students, since approximately a third of all athletes are generally graduating at the beginning of June each year. Using other electronic equipment such as apps and sms services, as well as by reducing the sample frequency of questionnaires are believed to be ways in which response rates could be improved.

The way injury is defined is crucial for the interpretation of the results of an injury registration study.[45] In this thesis, different injury types (injury, substantial injury, severe injury etc.) were explored. Injury was defined as any physical complaint resulting in reduced training volume, experience of pain, difficulties participating in normal training or competition, or reduced performance in sports, meaning that all kinds of physical complaints were recorded. This may have resulted in ache, exercise-induced muscle pain, cramps being recorded as an injury, even if these physical complaints have not been recorded as injuries in traditional studies. However, these physical complaints may be signs of muscle fatigue or soreness, which may indicate high physical stress on the human body and risk of a more severe injury. Besides, the injury definition used was based on self-reported injury consequences, meaning that if the physical complaint affected sports participation, training volume, performance or pain, it was recorded as an injury. This in line with the "all physical complaints" definition used in injury consensus reports.[46, 60-63]

Only a limited amount of information can be collected directly from athletes, meaning that data on injury diagnosis, detailed diagnostic information and injured tissue, among others, may not be gathered. In this project we had contact with medical personnel. Unfortunately the use of medical teams for data collection did not yield much with respect to injury reports, mainly due to communication issues and unwillingness to report injury data. However, by contacting the non-responding athletes using sms services or conducting athlete interviews by phone, studies have found it possible to gather important injury data as well as increasing the response rate.[49, 50, 84] However, more valid data on injury are likely gathered from a physical assessment performed by trained medical personnel, compared to these alternative approaches.

The reason for the high burden of injury in this age group is unclear. Even if a number of risk factors were identified, the risk of confounders cannot be ruled out. For instance, assessing the training load, based on hours of training exposure, may not adequately capture the true exposure load in certain sports or different training forms. Based on the training load, one hour of strength training is assumed to be of equal load as one hours of running, which may not cause the same injury risk for instance in a runner. Therefore risk factors were combined (i.e. Risk Index) in order to simulate the practical real-life situation of an athlete.

Targeting risk factors from a biopsychosocial perspective was considered to contribute to a more holistic perspective on risks for injury, while still allowing for studying the effects of single, or a combination of factors. However, social factors were not directly studied as risks in this study. Instead, psychosocial factors, which could be defined as the influence of social factors on an individual's mind and/or behaviour or the inherent interaction between these, were explored.[194] For instance, self-perceived stress as well as competence-based self-esteem could be considered as psychosocial factors, since these variables are likely affected by the athlete's interactions with team mates, parents, coaches and competitors (social context).

Even if not pure social factors were studied, different kinds of factors from psychological to biological variables were monitored in striving for a biopsychosocial perspective on injury risk.

The athletes had to estimate their training load, intensity and sleep volume repeatedly. Since multiple studies on non-athletes have shown subjective measure of physical activity to be highly overestimated[195-197] or underestimated,[198] the accuracy of self-reported data on training or sleep volume as expressed by young athletes could be questioned. However, these athletes are used to monitor training or sleep volume using training diaries, apps, watches, Global Positioning Systems (GPS) equipment etc., resulting in that these estimates might be fairly accurate and precise. However, objective measures of training load are preferred.

Unfortunately, the Nutrition Index does not consider energy intake. Instead, the focus was on the diet's nutritional content, leading to the study of diet composition and not energy intake. Since energy intake is likely related to recovery, eating disorders or injury occurrence,[127, 199, 200] monitoring energy intake would have provided one more dimension of injury risk.

Adolescents today appear to use email less frequently than those from the previous generation, for example, suggesting that apps and sms services may be the future of collecting self-reported data in this generation of athletes. Still, the most important aspect of an injury questionnaire, in order to monitoring subjects longitudinally, is how they are implemented and used, which relates to factors of the actual questionnaire (e.g., accessibility, irrelevant questions to the participants) and the social environment (e.g., peer-influence, reminders).[52]

5.5.3 Statistical considerations

At the start of the study, all athletes had to be injury free before they could be included in the risk factor analysis, resulting in a homogeneous cohort of non-injured athletes. However, the data analyses were limited to certain variables, and the omission of data, such as on injury mechanism and other biomechanical variables, may constitute a potential confounding effect. In addition, injury severity or multiple injury events were not analysed. Instead risk factors for first reported injury were analysed, regardless of injury severity. However, in order to fully understand injury risks in this cohort, it is important to identify injury risk for multiple events, which would have required a different statistical approach.[201-203]

Several different general techniques for handling missing data are suggested, such as using the mean of observed values, last value carried forward or imputing poor outcomes.[204] Due to missing data in determining risk factors for injury, leading to reduction of analytic power, missing values were estimated using multiple imputation techniques. However, multiple imputation techniques are based on the assumption of missing at random, and additionally require that sufficient large data sets exist. In paper IV, 4% of pre-event variables were not possible to calculate due to missing data, with 20% of the athletes having incomplete datasets. Therefore, sufficient data for multiple imputation techniques were assumed. Logistic regression analysis with baseline variables (age, sex, body mass index) as covariates showed that baseline data were not statistically predictive of incomplete data. It was therefore concluded that data were missing at random. In addition, comparing the imputed results with the non-imputed results showed an average increase in the HR of 11% for the pre-event variables in univariate Cox regression analyses, i.e. no relevant clinical change. Therefore, it was chosen to report all statistical analyses using the imputed data.

In paper I, even if time as a covariate was available, the choice of using Logistic regression instead of Cox regression was due to the fact that the analysis was based on two measurement points. Therefore, the event could have occurred before the second time point, making the assumption of time to first event invalid.

In the risk factor analyses, the number of 15 events per covariate was held.[205-207] Sample size was not based on power calculations. Instead, the focus was to include a considerable part of the population. Still, the power to identify risk factors is considered adequate. However, by including multiple events or injury based on severity may have enhanced statistical power. Unfortunately, a high number of athletes were not entered in the analysis due to constantly being injured, which may have potentially resulted in reduced statistical power. Consequently, this question if this statistical approach is suited for analysing risk factors in this population since a high number of cases were excluded.

By dichotomizing a variable, inevitable loss of information may occur, followed by reduced statistical power.[208] However, dichotomizing a variable may simplify the statistical analysis, leading to an easier interpretation of data. For instance, the interaction effects may be easier to interpret and extreme values may be easier to deal with after a variable has been dichotomized. The Nutrition Index was dichotomized based on sample sizes, whereas sleep weekdays was dichotomized at ≤ eight hours/day based on the NSF.[118] However, no precise sleep volume recommendation exists in young elite athletes, and everything from 8-10 hours/day is recommended in adolescents.[125, 209]

5.6 TRUSTWORTHINESS OF STUDY III

Qualitative research is appropriate when aiming to deepen the knowledge about people's perspectives and experiences. Since only a few studies have explored adolescent elite athletes, this approach was considered appropriate. An inductive content analysis approach was chosen, since the aim was to explore athletes' perceptions and experience of being injured, without influencing the data analysis on an existing preconceived theory.[210] Therefore, the emerging categories were derived directly from the raw data.

Credibility was likely enhanced by including athletes with a variety of injuries, from different schools, sports, and thereby exploring different perspectives of athletes' injury experiences. Besides, data analysis was conducted by authors with different professional background (physical therapist, occupational therapist) and experience levels (sport injuries, disabilities), which likely have led to improved credibility. It may be reasonable to assume that the interviewer developed techniques and more insight in the studied phenomenon over the course of the study, which may have influenced the follow-up questions and dependability.[211] However, all interviews were based on a semi-structured interview guide, and athletes were requested to participate and answer all questions to ensure uniformity in data collection.

To provide a deeper perspective of injury experience, the sample included both injury free athletes and athletes that were still injured and at the end of their rehabilitation. Even if only athletes who were willing to share their injury perceptions were included, sharing personal data like injury experience may still be difficult. This may affect what data is shared by the athletes. Pre-conceptions of elite sports from professional experience may have influenced the interview process and data analysis. At the same time, the findings have been synthesized in a mixed group using an iterative process. Data saturation related to injury experience may not have been achieved. In addition, due to the small sample the findings do not claim to be generalized. Instead, the focus was to provide an understanding of injury perceptions and experience in adolescent elite athletes, representing different sports, with a variety of injuries. Usage of replication strategies could be used to determine and enhance generalizability both in qualitative and quantitative designs.[212] Interestingly, the overarching theme was consistent across the interviews, and in line with previous reports.[187, 188] The transferability was facilitated by providing a distinct description of the context, characteristic of the athletes, injury data, sample selection, data collection and analysis. In addition, all categories were specified and quotations were presented.

5.7 CLINICAL IMPLICATIONS

The high injury prevalence of adolescent elite athletes studying at Swedish National Sports High Schools suggests that a national injury preventive strategy is needed. Based on the injury data and findings of the interviews, it is recommended that medical teams involving personnel from different health profession backgrounds with a special focus on sports medicine become an integral part of sports at this level. Today only a few schools have medical employees. Having clear pathways to a medical team is warranted and will likely lead to a faster diagnosis and more time-sensitive care. Finding the desired medical care is likely not an easy step for a young injured athlete with a possible identity-loss. However, developing medical team will not be enough to reduce the high injury burden. Athletes who do not recover within the expected time frame should be given an extended assessment by a national medical team consisting of different healthcare professionals,[213, 214] followed by a new rehabilitation plan. Consequently, all athletes should have access to a second assessment by a national medical team, organized by the Swedish Sports Confederation. Our results clearly show that athletes are injured for an extended duration of the season suggesting that the current or non-existing medical care is not working effectively for all athletes.

Based on the identified risk factors, it is recommended that coaches of adolescent elite athletes attempt to identify athletes with a high competence-based self-esteem, preferably during pre-season. The association between reducing the competence-based self-esteem a lower injury risk is not clear based on our findings. However, by identifying athletes with a high competence-based self-esteem might be a way of identifying athletes with a higher injury risk. In addition, athletes and coaches should be aware of the increased injury risk associated with increasing training volume, intensity while reducing the sleep volume at the same time. Still, it is inescapable to be an elite athlete without changing the training load or intensity in order to improve fitness level. By avoiding immediate changes to all three variables (in previously mentioned directions) athletes could maintain a high training load while adjusting the injury risk.

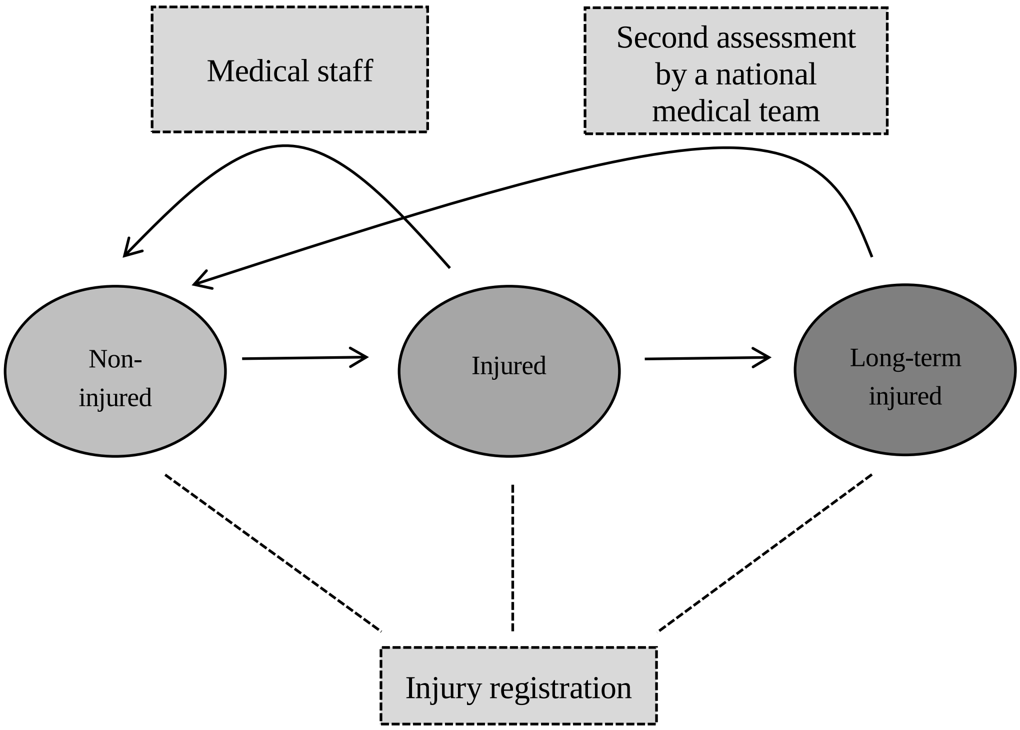


Figure 15. Proposed model for helping the injured athletes return to a non-injured state. The figure emphasizes the importance of injury registration at all three phases of injury status (non-injured, injured, long-term injured) for an athlete, irrespective of non-injured/injured status.

It is clear that adolescent elite athletes seem to have a high injury risk, and some are injured for long periods with substantial consequences. Therefore, interventions targeting injury prevention are needed. However, in order to sufficiently prevent injuries we need to systematically continue with collecting injury data. An ongoing injury surveillance registry for athletes at National Sports High Schools is mandatory, and would have several benefits for multiple reasons and stakeholders. It would provide an opportunity to monitor injury data at different season phases, between seasons, sports or age groups. It would also be used by coaches and athletes to evaluate their training methods and seasons. Finally, it would also be used to evaluate the success of interventions on the prevention of injuries. Therefore, it is recommended to incorporate an ongoing, easy to administer, injury registration surveillance, based on self-reports from athletes and reported data from medical staff (Figure 15). It is a utopia that every injury can be prevented. However, it is highly important to have a rehabilitation plan for athletes who are not recovered when expected. The young athletes should not be responsible to find the right medical care by themselves, but should be supported by medical staff.

The interview data yielded important considerations to facilitate the rehabilitation process for the injured athlete. The psychological response to an injury seems to vary during different phases of rehabilitation.[93, 188, 215] In addition, an injured athlete has to learn from their mistakes which occur pre- and post-injury, in order to be able to continue with elite sports. In addition, the response to injury, e.g. rehabilitation choices or attitudes, could result in long-term consequences in sports participation and performance. Due to the discrepancy in the rehabilitation process between the practitioner and the athlete, it may be important to explain the rehabilitation aim, stages as well as the athlete's role in the rehabilitation at the start of rehabilitation, thereby the athlete and practitioner will work in the same direction towards mutual goals while avoiding a mismatch in communication. Exploring tools, techniques for understanding the athlete's performance level, rehabilitation expectations or goals should not be neglected. In addition, spending time and effort in explaining the different phases of rehabilitation may be relevant to the practitioner when working with athletes in this population to enhance recovery outcomes. However, the extent to which these suggestions will improve the rehabilitation process and could be generalized to the wider athletic community needs to be further examined.

5.8 FUTURE RESEARCH

Even if this thesis has shed some light on injury risk and consequences in adolescent elite athletes, it has also identified important parts that warrant future research. It is therefore recommended to:

- Identify the reason and injury type for the athletes injured for a considerable amount of the season.

- Develop valid and easy to administer methods that can be used to identify injury data in young athletes.

- Explore optimal levels of sleep volume and nutrition for recovery and enhanced performance.

- Identify objective measure to identifiy the training load in athletes.

- Provide a coach's perspective on injury risk and injury prevention in National Sports High School.

- Identify risk factors for mutiple events and severity.

- Test interventions for modifying risk factors such as changes in trainng volume, sleep and competence-based self-esteem.

- Explore risk factors more in-depth in single sports.

6 CONCLUSION

- The high average weekly injury prevalence, 1-year injury prevalence, and that more than a third of the recovered injuries resulted in absence from normal training for at least four weeks revealed that the injury risk and injury severity is high in adolescent elite athletes.

- Injuries have consequences on sports involvement and performance, but may also lead to experiencing negative psychological responses (frustration, anger), daily living activity consequences (sleep disturbances, study issues), as well as feelings of loneliness, self-blame or self-criticism, in adolescent elite athletes.

- Sports involvement seems to constitute an important part of an adolescent elite athlete's life, while injury may lead to a loss of identity.

- Female athletes reported higher average injury prevalence and substantial injury prevalence compared to male athletes.

- Between 19-43% of the adolescent elite athletes, did not meet the national nutritional guidelines and sleep volume recommendation during weekdays.

- A high competence-based self-esteem and increase in training load and training intensity, while at the same time decreasing sleep volume, emerged as risk factors for injury.

- Directing targeted preventive interventions on knee and foot injuries will address both the majority of and the specific injuries with most serious consequences in adolescent elite athletes.

- Medical teams, accessible to all athletes at each National Sports High School, are warranted to reduce the unhealthy behaviour, injury risk and help athletes return to sports safely following injury. These medical teams should be aware of the multiple consequences of injury in adolescent elite athletes.

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