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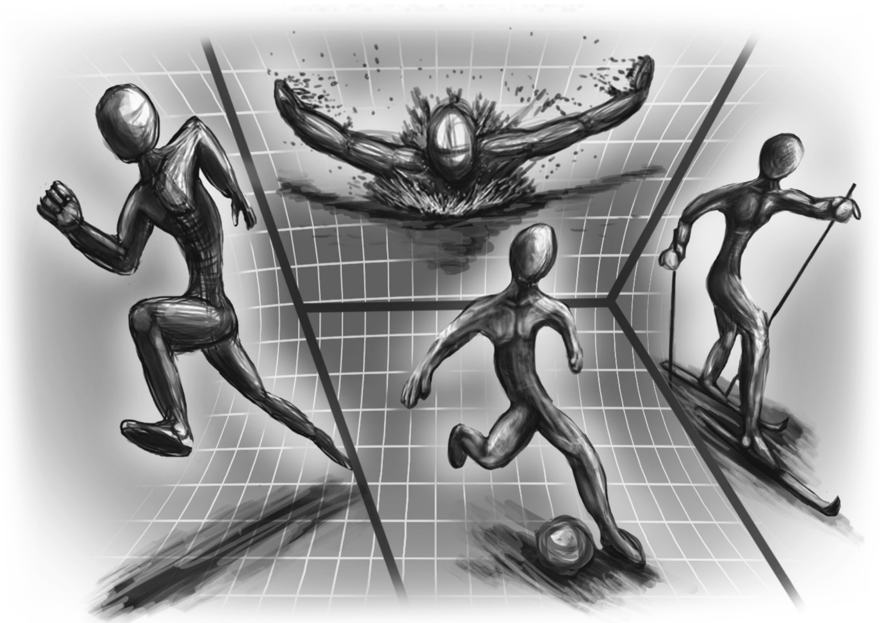

Leena Ristolainen

Helsinki 2012

Sports Injuries in Finnish Elite Cross-Country Skiers, Swimmers, Long-Distance Runners and Soccer Players

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Esitetään Jyväskylän yliopiston liikunta- ja terveystieteiden tiedekunnan suostumuksella julkisesti tarkastettavaksi yliopiston vanhassa juhlasalissa S212 helmikuun 24. päivänä 2012 kello 12.

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ABSTRACT

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In sports with different exercise-loading characteristics, acute and overuse injury profiles and gender differences in injuries were investigated. In addition, training-related risk factors for overuse injuries in endurance athletes were studied. This twelve-month retrospective questionnaire study comprised Finnish elite cross-country skiers (n=149), swimmers (n=154), long-distance runners (n=143) and soccer players (n=128) aged 15–35 years. Questionnaires were sent to the athletes in each sports at the end of the 2006 competition season. Athletes who ended their sports career because of injury were studied in more detail by means of a telephone interview (n=20) 7-11 months after the questionnaire. Over 70% of soccer players and one-third of endurance athletes had sustained at least one acute injury during the past twelve months. In soccer players and cross-country skiers the most common acute injury site was the ankle. In skiers, acute and overuse injuries occurred mainly in sports other than their own sports and the same was true for acute injuries in swimmers. However, overuse injuries in swimmers mainly originated from swimming, with the shoulder region as the most common anatomical site. Nearly every second athlete reported at least one overuse injury, with the highest injury frequency, most commonly in the foot, occurring among long-distance runners. Soccer players and runners reported absences of nearly two months on average from training and competitions owing to acute or overuse injury. Male athletes had higher prevalence of at least one acute injury, and among runners males had more commonly at least one overuse injury than females. Among endurance athletes, vigorous training, defined as more than 700 hours/year, and rest and recovery time of less than two days a week in the training season predisposed to overuse injury. Older athletes had higher risk for overuse injury, and especially tendon overuse injury. Female athletes (13%) ended their career more often because of injury than male athletes (5%). The most prevalent injury was in the knee, shoulder or ankle. Most sports career terminators (70%) reported injury-related mild or moderate permanent disability. In conclusion, type of loading was strongly associated with the anatomical location of an overuse injury. In cross-country skiing and swimming a significant proportion of acute injuries occurred in other than the athlete's main sports. Vigorous athletic training without sufficient rest and recovery time may be a risk factor for an injury, especially an overuse injury. Severe injuries may terminate an athlete´s sports career and cause permanent disability.

Keywords: cross-country skiing, swimming, long-distance running, soccer, athletic injury, gender, risk factor, sports career

TIIVISTELMÄ

Ristolainen, Leena Hannele
Urheiluvammat suomalaisilla huipputason hiihtäjillä, uimareilla, kestävyysjuoksijoilla ja jalkapalloilijoilla
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Väitöskirjatutkimuksen tavoitteena oli selvittää eri tavoin kuormittavien urheilulajien vammaprofiilia ja vammojen eroja sukupuolten välillä. Sen lisäksi tutkittiin harjoitteluun liittyviä rasitusvammojen riskitekijöitä kestävyysurheilijoilla. Suomalaiset 15-35 -vuotiaat mies- ja naishuippu-urheilijat osallistuivat 12 kuukauden retrospektiiviseen kyselytutkimukseen. Urheilijat olivat maastohiihtäjiä (n=149), uimareita (n=154), kestävyysjuoksijoita (n=143) ja jalkapalloilijoita (n=128). Kysely lähetettiin urheilijoille vuonna 2006 kilpailukauden jälkeen. Ne urheilijat, jotka ilmoittivat lopettaneensa kilpaurheilunsa urheiluvamman takia, haastateltiin puhelimitse 7-11 kuukautta postikyselyn jälkeen (n=20). Jalkapalloilijoista yli 70% ja kestävyysurheilijoista joka kolmannelle sattui vähintään yksi äkillinen vamma edellisen vuoden aikana. Jalkapalloilijoiden ja maastohiihtäjien yleisin äkillinen vamma kohdistui nilkkaan. Maastohiihtäjien ja uimareiden äkilliset vammat ja hiihtäjien rasitusvammat tapahtuivat pääosin muissa lajeissa kuin heidän omassaan. Uimareiden rasitusvammat olivat pääosin peräisin uinnista ja tyypillisesti vamma oli olkapään alueella. Lähes joka toisella kyselyyn vastanneista urheilijoista oli ollut vuoden aikana vähintään yksi rasitusvamma ja kestävyysjuoksijoilla niitä oli eniten. Juoksijoiden yleisin rasitusvamma oli jalkaterän alueella. Jalkapalloilijat ja juoksijat joutuivat olemaan pois harjoittelusta ja kilpailuista keskimäärin lähes kaksi kuukautta äkillisten vammojen tai rasitusvammojen takia. Naisurheilijoihin verrattuna miehillä oli useammin vähintään yksi äkillinen vamma. Vähintään yhden rasitusvamman esiintyminen oli miesjuoksijoilla yleisempää kuin naisjuoksijoilla. Runsas harjoittelu (yli 700 tuntia/vuosi) ja alle kahden päivän viikoittainen lepoaika harjoittelukaudella altisti kestävyysurheilijoita rasitusvammoille. Vanhemmilla kestävyysurheilijoilla oli suurempi riski saada erityisesti jänteen rasitusvamma. Naisista 13% ja miehistä 5% lopetti urheilu-uransa vamman takia. Näillä urheilijoilla vammat kohdistuivat yleisimmin polveen, olkaniveleen tai nilkkaan. Yli 70% vamman vuoksi urheilu-uransa lopettaneista urheilijoista raportoi vammasta aiheutuneen pientä tai kohtalaista pysyvää haittaa toimintakyvylle. Tämän tutkimuksen perusteella voidaan todeta, että kuormituksen laatu on suoraan yhteydessä rasitusvamman esiintymiselle. Hiihtäjien ja uimareiden äkillisistä vammoista suurin osa tapahtuu muussa kuin omassa lajissa. Etenkin kestävyysurheilijoilla runsas harjoittelu vähäisen palautumisen lisäksi altistaa rasitusvammoille. Urheilija voi joutua lopettamaan urheilu-uransa vakavan vamman vuoksi ja vamma voi aiheuttaa urheilijalle myös pysyvää haittaa.

Avainsanat: hiihto, uinti, kestävyysjuoksu, jalkapallo, urheiluvammat, sukupuoli, riskitekijä, urheilu-ura

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Helsinki, January 2012

Leena Ristolainen

ABBREVIATIONS

ACL	Anterior cruciate ligament
ANOVA	Analysis of variance
BMI	Body mass index
CI	Confidence interval
ICC	Intraclass correlation coffiecient
OR	Odds ratio
p-value	Statistical significance
RR	Relative risk
SD	Standard deviation

FIGURES

TABLES

APPENDICES

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by the Roman numerals I – IV.

I Ristolainen L, Heinonen A, Turunen H, Mannström H, Waller B, Kettunen JA, Kujala UM. 2010. Type of sport is related to injury profile: A study on cross country skiers, swimmers, long-distance runners and soccer players. A retrospective 12-month study. Scand J Med Sci Sports 20 (3), 384-393.

II Ristolainen L, Heinonen A, Waller B, Kujala UM, Kettunen JA. 2009. Gender differences in sport injury risk and types of injuries: A retrospective twelve-month study on cross-country skiers, swimmers, long-distance runners and soccer players. J Sports Sci Med 8 (3), 443-451.

III Ristolainen L, Kettunen JA, Waller B, Heinonen A, Waller B, Kujala UM. Training-related risk factors in the etiology of overuse injuries in endurance sports. (submitted).

IV Ristolainen L, Kettunen JA, Kujala UM, Heinonen A. 2011. Sport injuries as the main cause of sport career termination among Finnish top-level athletes. Eur J Sports Sci. DOI:10.1080/17461391.2011.566365.

CONTENTS

1 INTRODUCTION

Regular physical activity is essential for optimal body function and health. Physical activity is associated with reduced risk for premature morbidity and mortality (Kujala et al. 2003a, Kujala 2004, Nelson et al. 2007). In addition, exercise improves aerobic and functional capacity and muscle strength among healthy individuals and those with chronic disease (Schjerve et al. 2008, Kujala 2009). Moderate-intensity activity (150 minutes/week), vigorous physical activity (75 minutes/week) or aerobic activity in episodes of at least 10 minutes throughout the week have a positive effect and reduces the risk for many adverse health outcomes (U.S. Department of Health and Human Services 2008).

However, sports participation carries a risk for injuries and in some cases can lead to permanent disability (Bahr & Holme 2003). Vigorous physical activity particular may have adverse health effects (van Mechelen et al. 1996). Although permanent disabilities are uncommon (Kujala et al. 1995b, Kujala et al. 2003b), the effect of long-standing athletic activity on the development of osteoarthritis should not be neglected (Kujala et al. 1995a, Kujala et al. 2003a). Numerous sports-related injuries occur each year, resulting in disability and time lost from training in addition to substantial medical costs (McMaster et al. 1998; Murphy et al. 2003). Treatment of sports injuries is often difficult, expensive and time consuming (Parkkari et al. 2001, Kujala et al. 2003b). The incidence of sports injuries is high; fortunately, severe injuries are rare (Kujala et al. 2003b).

In Finland, during 2009, 348 000 sports-related injuries were sustained by people over age 15 (Haikonen & Parkkari 2010). Numerically, this represents the largest category (32%) of injuries reported that year. Sports-related accidents were sustained by men more often (68%) than women (32%). Injury risk was high in floorball, soccer and ice hockey. A smaller injury risk was observed in cross-country skiers and walkers (Haikonen & Parkkari 2010).

There is a general consensus that the incidence of injury is greater in competition than training sessions, especially in soccer (Faude et al. 2005, Hägglund et al. 2009), and previous injury when coupled with inadequate rehabilitation, is a risk factor for subsequent injury (Taunton et al. 2003, Hägglund et al. 2006). Various methods of preventing sports injuries, such as use of insoles, external joint supports and multi-intervention training programs, have been proposed (Parkkari et al. 2001, Aaltonen et al. 2007, Pasanen et al. 2008). Injury prevention remains an important goal for clinicians and researchers.

Our aim was to study the occurrence and consequences of athletic injuries in sports with different loading patterns to determine specific injury profiles. We also studied gender differences in sports injuries. Training-related risk factors for an overuse injury were studied among endurance athletes. Athletes who reported ending their sports career were interviewed in more detail on the mechanisms and consequences of injuries. The target group of this study comprised Finnish top-level cross-country skiers, swimmers, long-distance runners and soccer players. A twelve-month retrospective study design was used.

2 LITERATURE

2.1 Sports injuries

"Sports injuries" is a name applied to all types of damage occurring in the course of sporting activities (van Mechelen et al. 1992b). Injuries are variously defined. The most common definitions are based on time lost from training or competitions, or on medical treatment, defined as injuries requiring treatment by a physician. However, this may or not result in time lost from training or competitions (Brooks & Fuller 2006).

No consensus exists on definitions of acute and overuse injury (Parkkari et al. 2001), and hence definitions vary across studies. In some studies, all injuries are grouped together, as in Junge et al. (2009) where the definition (traumatic and overuse) was any new musculoskeletal complaint sustained due to competition and/or training that received medical attention irrespective of whether or not it led to absence from competition or training. In the study by Yard et al. (2009), a reportable injury was an injury that occurred as a result of participation in an organized competition or practice, required medical attention, and resulted in restriction on participation for one or more days beyond the day of the injury. Many of the definitions of a sports injury are based on studies of soccer injuries (Junge & Dvorak 2000, Arnason et al. 2004, Faude et al. 2006). A running-related injury has been defined as an injury to muscles, joints, tendons, and/or bones attributed by the runner to running (Macera et al. 1989).

The problems of definition make it difficult to compare studies (van Mechelen et al. 1992b). Differences in study designs also render comparison between studies difficult. However, how sports injuries are defined is important, since the definition used constitutes the basis for research on such injuries (van Mechelen 1992b, Junge & Dvorak 2000, Brooks & Fuller 2006). It also guides the data collection and influences the application of the study outcome to sports and exercise medicine (van Mechelen 1992b, Junge & Dvorak 2000, Brooks & Fuller 2006).

2.1.1 Acute and overuse injuries in sport

Junge and Dvorak (2000) have defined an acute injury as an injury caused by a macrotrauma or as an injury which caused a trauma, the reason being, e.g., tackling, kicking or running. Faude et al. (2006) classified a traumatic injury as an injury which was caused by a single traumatic incident. An acute injury has also been defined as any injury or condition which did not exist prior to the date of injury occurrence (Giza et al. 2005). In many studies, an acute sports injury is defined as injury with a clear onset as a result of trauma, and which has occurred in training or competition (Arnason et al. 2004, Hägglund et al. 2009), and has caused at least one day away from training and/or competitions (Hawkins & Fuller 1999, Arnason et al. 2004, Alonso et al. 2009). An acute injury has also been described as any physical injury that keeps an athlete away from at least one training session or competition, or needs a physician's care (Söderman et al. 2001, Orchard & Seward 2002).

An overuse injury is defined as an injury which is caused by the consequences of repetitive microtraumas (Junge & Dvorak 2000). Lüthje et al. (1996) defined an overuse injury as a pain syndrome of the musculoskeletal system appearing during physical exercise without any known trauma, disease, deformity or anomalia that have given previous symptoms. An overuse injury has also been described as an injury with an insidious onset with a gradually increasing intensity of discomfort without an obvious trauma (Arnason et al. 2004). The injury causes worsening pain during or after exercise and continuation of loading causes even worse pain and may stop exercise completely (Brukner & Bennell 1997, Beck 1998). A chronic injury has also been classified as any injury with insidious progression that existed prior to the date of the injury's occurrence or an exacerbation of a previously existing condition (Giza et al. 2005).

2.1.2 Types of acute and overuse injuries

Acute injuries

Sports injuries can be classified according to injury type and tissue. Acute injuries usually occur to the muscle, ligament, or skin. Bone or joint injuries are rarer, but can also be more severe (Brukner & Khan 2006). Cramps, strains with different grades, and contusion are common acute injuries in the muscle (Brukner & Khan 2006). Cramp is a sudden muscle contraction which is painful and may occur in any muscle, but mostly the calf. The etiology of muscle cramp is poorly understood (Maquirriain & Merello 2007). Muscle strain is most prevalent in sudden acceleration or deceleration (Pleacher & Glazer 2005). Highest grade muscle tears can be very damaging. The most common strain among athletes is hamstring strain (Croisier 2004). Contusions can result from a direct blow, especially in team sports such as soccer, football, ice hockey and basketball. The most common site of muscle contusions is the thigh (Chomiak et al. 2000).

Ligament injuries are strains of various grades from stretched fibers to a complete ligament tear with excessive joint laxity (Pleacher & Glazer 2005, Brukner & Khan 2006). Ankle and knee ligament injuries in particular are common (Arendt and Dick 1995, Baumhauer et al. 1995, Hägglund et al. 2009). Anterior cruciate ligament (ACL) injuries are among the most severe knee injuries, limiting training and competition time (Dugan 2005). Moreover, severe injuries in the knee increase the risk for degenerative joint disease (Thelin et al. 2006). Skin injuries include abrasions and lacerations (Basler et al. 2004). Acute tendon injury can be a sudden tear of the tendon, the rupture usually occurring in an older athlete with history of injury of the tendon (Brukner & Khan 2006). The most common acute tendons injuries are either partial or complete rupture of the Achilles and supraspinatus tendons (Kannus & Natri 1997). Dislocations and subluxations of joint injuries can occur after trauma. The shoulder joint has the greatest range of motion of any joint in the body and as a result is particularly susceptible to dislocation and subluxation (Good & MacGillivray 2005). Joint injuries can also result from surrounding joint capsule or ligament injuries (Brukner & Khan 2006). A bone fracture can occur from a direct blow or a fall. Soft tissue damage is often associated with fracture. Also articular cartilage defects may occur in severe joint injuries. Major nerve injuries are unusual in athletes. However, the ulnar nerve and the peroneal nerve can be injured from a direct blow (Brukner & Khan 2006). Concussion with mild traumatic brain injury can be induced by hits and blows on the head.

Overuse injuries

Overuse injuries can occur to the same tissues as acute injuries, but the pathology of these injuries is different. The most common overuse injury occurs to the tendon and is called tendinopathy (Khan et al. 1999). It is prevalent in the Achilles, patellar and rotator cuff tendons. There is no clear understanding of the pathology of tendinopathy (Khan et al. 1999). Another common overuse injury among athletes is situated in the bursae. Bursae such as the subacromial bursa and greater trochanteric bursa can become irritated and inflamed (Adkins & Figler 2000, Pleacher & Glazer 2005). Another overuse injury prevalent among athletes is a stress fracture, which is a result of a microfracture in bone caused by repetitive physical loading (Bennell et al. 1996, Iwamoto & Takeda 2003, Snyder et al. 2006). The most common stress fractures occur to the tibia, metatarsals, fibula, tarsal navicular and femur (Iwamoto & Takeda 2003, Laker et al. 2007). Among ballet dancers, figure skaters and gymnasts repetitive bone stress in the spine may lead to a spondylolysis. Although upper limb stress fractures are less common than those of the lower limbs, stress fractures occur in sports where athletes are dominantly using an upper limb such as in swimming and tennis (Brukner 1998).

Overuse injuries in the muscle are focal tissue thickening, chronic compartment syndromes and muscle soreness (Pleacher & Glazer 2005, Brukner

& Khan 2006). Overuse damage to muscle fibers are a result of repetitive microtrauma. Focal areas, such as tissue thickening, can be palpated and can cause local pain. Overuse damage can also negatively affect rapid contraction and relaxation of the muscle (Brukner & Khan 2006). Chronic compartment syndrome is the most prevalent in the lower leg (Brukner & Khan 2006). Compartment syndrome can also be located in the forearm in, e.g., tennis players. Intracompartmental pressure increases and may cause local muscle swelling. The thigh fascia prevents expansion of the muscle and impairs the blood supply (Englund 2005, McDonald & Bearcroft 2010). Muscle soreness, known as delayed onset muscle soreness, is typical 24 to 48 hours after unaccustomed physical activity. The etiology of delayed onset muscle soreness is still poorly understood (Herbert et al. 2011).

Joint overuse injuries are inflammatory changes associated with repetitive loading, and are known as synovitis or capsulitis. Examples of such injuries are sinus tarsi syndrome of the subtalar joint and synovitis of the hip joint (Adkins & Figler 2000, Brukner & Khan 2006). Skin overuse injuries are blisters and calluses. A blister can occur at any site of friction with an external source, such as shoes or sports equipment (Basler et al. 2004). Dermatologic complaints are common among athletes, for example long-distance runners (Jaworski 2005). Nerve entrapment syndromes occur as a result of swelling in the surrounding soft tissues. Examples of the latter overuse injuries are entrapments in the peroneal nerve, suprascapular nerve, posterior tibial nerve at the tarsal tunnel and interdigital nerves, a condition known as Morton´s neuroma. Nerve entrapment represents an uncommon but important cause of lower limb pain, especially among runners (Peck et al. 2010). Overuse injuries in ligaments are rare (Brukner & Khan 2006).

2.1.4 Severity of injuries

In their review, van Mechelen et al. 1992b describe severity according to six criteria: the nature of the sports injury, the duration and the nature of treatment, sporting and working time lost, permanent damage and costs. Injury severity is correlated with the loss of time from training or/and competition. The severity of injury and time loss due to injury is defined in many different ways (Table 1).

2.1.5 Recurrent injuries

Fuller et al. (2006) stated in their consensus statement that a recurrent injury was an injury of the same type and occurred to the same site as the index injury. A recurrent injury occurred after an athlete´s return to full participation from the index injury. Moreover, "early recurrence" was defined as a recurrent injury that occurred within two months of an athlete´s return to full participation, "late occurrence" if the injury occurred 2 to 12 months after full participation and "delayed recurrence", if the injury occurred over 12 months after full participation. A recurrent injury has also been defined as an injury that occurs to a location on the body that previously sustained the same type of injury

(Waldén et al. 2006, Swenson et al. 2009), and occurred on the same side as the previous injury during the season (Waldén et al. 2006). A subsequent injury was defined as any injury to the same or a different body part that occurred after the runner´s initial injury (Rauh et al. 2006). Brooks and Fuller (2006) state that an injury reported as recurrent on the above-mentioned definitions may not be a true recurrent injury, as the injury may be in the same muscle group but in a different location in the muscle.

TABLE 1 Different definitions of severity of injury and time loss from training and competition.

Authors	Year	Injury definition
Arnason et al.	2004	Three categories according to duration: mild injury (1 to 7 days) absence from training and/or competition), moderate injury (8 to 21 days), and severe injury (more than 21 days).
Dvorak et al.	2000	Severe injury defined as complaints lasting more than 4 weeks or severe tissue damage such as fracture.
Faude et al.	2005	Three categories according to duration: minor injury (less than 7 days), moderate (7 to 30 days), and major injury (over 30 days).
Fuller et al.	2006	Number of days that have elapsed from the date of injury to the date of the athlete´s return to full participation in training and competition.
Fuller et al.	2007	Four categories according to duration: minimal/slight (1 to 3 days), mild (4 to 7 days), moderate (8 to 28 days), and severe (over 28 days plus season ending injuries).
Orchard & Seward	2002	Severe injury was defined as the average number of games missed per injury.
Peterson et al.	2000	Three categories: mild injury (symptoms lasting up to one week or absence for one week), moderate injury (symptoms lasting from two to four weeks and absence of less than four weeks), and severe injury (symptoms for more than four weeks or absence for 4 or more weeks).

2.2 Injury incidence and prevalence

Data obtained from epidemiological studies of sports injuries are necessary for developing different strategies for injury prevention and rehabilitation (Brooks & Fuller 2006). The most basic measure of injury occurrence is a simple count of injured persons (Caine et al. 2006). Other common measures are relative proportions of injuries and incidence of injuries (Brooks & Fuller 2006). Injury incidence has also been calculated as the number of new sports injuries divided by the amount of exposure to injury (Orchard & Seward 2002). Incidence is the occurrence of new cases of injuries in an athlete during a specific period of time (Phillips 2000, Caine et al. 2006, Knowles et al. 2006b), or the number of new injuries during a period divided by a total number of sportspeople during that time (van Mechelen et al. 1992b, Phillips 2000).

The injury incidence rate is commonly calculated as the number of injuries sustained divided by total time-at-risk, e.g., injuries/1000 exposure hours (Caine et al. 2006). It can also be calculated as injuries/1000 player hours (Hawkins & Fuller 1999) or injuries/1000 matches or injuries/1000 athletes-exposure (Caine et al. 2006). van Mechelen and co-workers (1992b) preferred to calculate the incidence of sports injuries in relation to exposure such as hours. Rates are then more comparable between different studies.

In sports epidemiology, the prevalence of injury is the proportion of athletes who have an existing injury at any given point in time (Knowles et al. 2006b) or the proportion of athletes in a population-at-risk who have an existing injury at any given point in time (Caine et al. 2006). Prevalence is thus used as an estimate of how common a condition is in a population over a certain period of time.

2.3 Types of exercise-related loading in different sports

Physical loading modalities can be classified into five different exercise loading groups: repetitive (non-impact), repetitive (low-impact), high-magnitude, odd-impact and high–impact (Nikander et al. 2005). Swimming and cycling represent non-impact repetitive sports, cross-country skiing and long-distance running represents repetitive low-impact exercise loading, soccer as a contact sport represents the odd-impact loading modality, and volleyball is considered to represent high-impact exercise loading (Nikander et al. 2005). As participants in these sports have been selected as a target group in this thesis, their injury profile is reviewed in more detail.

2.3.1 Cross-country skiing

Cross-country skiing is an endurance sport with low-impact exercise loading and consists of repetitive pliant movements without impact. Cross-country skiing is a common sport in the Nordic countries. However, it is not very widely spread; also, studies on skiing injuries are few (Orava et al. 1985, Eriksson et al. 1996, Morris & Hoffman 1999, Engebretsen et al. 2010). Nowadays there are two dissimilar skiing techniques: the classic technique, using traditional diagonal strides and the skating technique, where ski-skating predominates. In the classic skiing technique, the spine is loaded from repetitive extension to deep flexion movements while in the skating technique the spine is held in a more stable and more vertical position (Eriksson et al. 1996, Bahr et al. 2004). In addition, in the classic style, rotational loading on the low back is common.

The minimum length of competition skis is the height of the skier minus 100 mm and the minimum width 40 mm. Skis must weigh at least 750 g per pair. Two poles of equal length must be used with one pole held in each hand. Maximum pole length must not exceed the competitor's height, nor be below the hips (measurements are taken by placing the tip of the pole on the ski in front of the binding). However there are no limitations with regard to the material and make of ski boots and bindings. Competition can vary from sprint skiing competitions (0.8 – 1.8 km), which are held over a short period during the same day with a short resting time, to long competitions such as the 30 kilometers in women and 50 kilometers in men in one day (International Ski Federation, FIS 2011).

Cross-country skiing has been recommended as a safe sport and suitable activity for physical fitness (Smith et al. 1996). Cross-country skiing is also advocated for rehabilitation (Smith et al. 1996). Previous reports have shown a low number of skiing-related injuries in cross-country skiing (Sandelin et al. 1980, Orava et al. 1985, Renstrom & Johnson 1989). The incidence of injuries in cross-country skiing reported in different studies varies between 0.2-3.0 per thousand skier days (Westlin 1976, Sandelin et al. 1980, Renstrom & Johnson 1989, Hunter 1999) or 1.3-2.2 injuries per 1000 exposure hours among the Finnish national population aged 15 and over (Haikonen & Parkkari 2010).

The existence of two different techniques, increased velocity and new equipment may increase the number of injuries in cross-country skiing, especially among those using the skating technique (Butcher & Brannen 1998). Earlier studies have shown that typical injuries in cross-country skiers are localized in the low back (Mahlamäki et al. 1988, Eriksson et al. 1996, Bahr et al. 2004, Bergstrøm et al. 2004). Some authors have reported that the diagonal (classic) skiing style causes more low back pain to the skier than the skating-skiing style (Eriksson et al. 1996, Bergstrøm et al. 2004, Alricsson & Werner 2005). However, conflicting rates of low back injury between the skating and classic techniques have been reported (Eriksson et al. 1996, Butcher & Brannen 1998, Bahr et al. 2004).

Injury to the ulnar collateral ligament (UCL) of the metacarpophalangeal (MCP) joint of the thumb (skier´s thumb) is the one of the most common acute injury in the upper extremities. It happens when skier falls and the ski pole forces the thumb to deviate radially (Renstrom & Johnson 1989, Fricker & Hintermann 1995).

Two-thirds of all injuries in cross-country skiers are overuse injuries (Bergstrøm et al. 2004). According to Morris and Hoffman (1999), most overuse injuries are caused by errors of technique or by equipment. The other common overuse injuries in cross-country skiers are the leg (medial tibial syndrome), the ankle (Achilles tendon) and the great toe in the metatarsophalang joint (MTP, skier's toe) (Renstrom & Johnson 1989, Fricker & Hintermann 1995, Morris & Hoffman 1999). Usually, injuries are located in the muscles and tendons (Sandelin et al. 1980, Renstrom & Johnson 1989). Orava et al. (1985) reported that only 40% of overuse injuries in skiers originated in cross-country skiing. It indicates that cross-country skiing is a safe sport in itself.

2.3.2 Swimming

A popular physical activity such as swimming is also an endurance sport which has a great number of movements without ground impact. This sport represents the repetitive, non-impact loading modality. In swimming the repetitive loading focus is on the upper extremities. A swimmer performs more than one million strokes annually with each arm and over 90% of the propulsive force comes from the upper extremities, and involves repetitive overhead movements (Pink & Tibone 2000, Sein et al. 2010). Pink & Tibone (2000) reported that elite swimmers with intensive training and competition may perform over 2500 overhead movements in a day. To get further in the water, the swimmer must use large arm moments (Sein et al. 2010).

In swimming the most common competition techniques are freestyle, backstroke, breaststroke and butterfly, each of which has its own rules. The competition swimming pool is 25 or 50 meters long. Since the beginning of 2010 all swimsuits must be made from textiles and for men may not extend above the navel or below the knee, while for women a swimsuit may not cover the neck or extend past the shoulder or below the knee (Fédération Internationale de Natation, FINA 2011).

There are many swimming competition seasons during the year. A competition event varies from 20 seconds (50 m freestyle) to 14 minutes (1500 m freestyle). Swimmers enter many competitions during one or two days and resting times between competitions may be short.

The incidence of at least one swimming injury has been reported to vary from 22% to 37% in young elite athletes (Baxter-Jones et al. 1993, Maffulli et al. 2005). Bak et al. (1989) reported 0.9 injuries per swimmer per 1000 hours of swimming. Wolf et al. (2009) in turn reported an injury incidence of 3.9 injuries per 1000 exposures in swimmers. The most common musculoskeletal problem among competitive swimmers is shoulder pain (Richardson 1987, Pink & Tibone 2000, Wolf et al. 2009, Sein et al. 2010). The reported incidence of shoulder injury during one year in swimmers has varied from 26% to 35% (McMaster & Troup 1993, McMaster et al. 1998, Wolf et al. 2009). Overuse shoulder injury in swimmers may be the aetiology leading to instability and impingement of the shoulder (Richardson 1987, Allegrucci et al. 1994, Bak & Fauno 1997, McMaster et al. 1998, Pink & Tibone 2000, Weldon & Richardson 2001)

Another common location of overuse injuries is the knee (Richardson 1987, Rodeo 1999) and the groin (Grote et al. 2004), especially in swimming the breaststroke. Low back injuries are also common among swimmers, especially swimming the butterfly, because body position in the water is maintained by the low back (Richardson 1987, Ferrell 1999).

2.3.3 Long-distance running

Long-distance running represents the repetitive, low-impact exercise loading modality. In long-distance running, the structures of the lower extremities are exposed to a large number of repetitive forces (van Mechelen 1992a, Hreljac 2004, Laker et al. 2007).

Running has become a popular form of exercise (van Mechelen 1992a, Parkkari et al. 2004, Wen 2007) for which many health benefits have been reported, including a positive effect on cardiovascular health (Thompson et al. 2007, Schjerve et al. 2008). Requa et al. (1993) found a higher risk for injury from running than, e.g., team sports on the recreational level, whereas Parkkari et al. (2004) found running to be safer than team sports.

In track and field, long-distance running is usually meant when athletes compete distances 3000 meters and over. Long-distance running in particular measures a person´s aerobic fitness. A runner's number of competitions varies according to his/her race distances. If an athlete competes only in the marathon (42.195 km) he/she usually has fewer competitions a year than an athlete competing in a 3000-meter event (International Association of Athletics Federations, IAAF 2011).

Among runners, overall injury incidence rates of from 13 to 17 per 1000 athletes exposure (Rauh et al. 2000, Rauh et al. 2006), and overall injury rates of from 37% to 56% over twelve months (van Mechelen 1992a, Taunton et al. 2003) have been reported. The incidence rate of overuse injury in runners varies from 2.5 to 12 injuries per 1000 hours of training (Lysholm & Wiklander 1987, van Mechelen 1992a) or from 24% to 68% over twelve months (Lysholm & Wiklander 1987, Marti et al. 1988, Macera et al. 1989, Wen et al. 1997). Injuries in long-distance runners are mainly overuse injuries because of the amount of repetition of the same movement (van Mechelen 1992a).

The etiology of overuse injuries is multifactorial. Overuse injuries may be caused by anatomical (Lysholm & Wiklander 1987, Hreljac 2005) or biomechanical factors (Rolf 1995, Hreljac 2005). Running distance, training program and exercise type, rapid increase in training intensity or weekly running distance has been shown to be associated with running injuries (Lysholm & Wiklander 1987, Marti et al. 1988, Tenforde et al. 2011). Among runners, most of overuse injuries are located in or below the knee - mainly in the knee, lower leg and ankle (van Mechelen 1992a, Taunton et al. 2002, Taunton et al. 2003). The most common overuse running injuries are Achilles tendinopathy and patellofemoral pain syndrome (Taunton et al. 2002, Knobloch 2008).

2.3.4 Soccer

Soccer is a contact sport involving jumping, reversing, rotation, and high risk for impacting loads and sprains, and thus represents the odd-impact loading modality.

Soccer is one of the most popular leisure-time and elite physical activities globally. Soccer teams have eleven players, one of whom keeps goal. Players wear a shirt, shorts, knee-high socks, shin guards and football boots. The ball is a 68-70-cm sphere and air-filled. Playing field is 100–110 meters long and 64–75 meters wide. A soccer game consists of two halves, lasting 45 minutes each, with a pause between halves lasting not longer than 15 minutes. Soccer is played on grass or artificial turf (Fédération Internationale de Football Association, FIFA 2011).

Soccer studies have shown 13-28 injuries per 1000 match hours or 1-12 injuries per 1000 training hours (Lüthje et al. 1996, Faude et al. 2005, Giza et al. 2005, Hägglund et al. 2005, Jacobson & Tegner 2007, Hägglund et al. 2009).

Injuries are located mainly in the thigh, the knee, the shin and the ankle, and are usually contusions and muscle strains or ligament sprains (Kujala et al. 1995b, Junge et al. 2004a, Faude et al. 2005, Jacobson & Tegner 2007). More than half of all the acute injuries in soccer are caused by contact with other person, for example during tackling situations (Engström et al. 1991, Hawkins & Fuller 1998, Junge et al. 2004a, Junge et al. 2004b, Faude et al. 2005). Soccer players have fewer overuse injuries than acute injuries, and acute injuries have been the main focus of studies (Sandelin et al. 1985, Kujala et al. 1995b, Junge et al. 2004a, Hägglund et al. 2009). The reported incidence of overuse injuries varies between 6%-41% (Lüthje et al. 1996, Peterson et al. 2000, Faude et al. 2005, Giza et al. 2005, Hägglund et al. 2005, Waldén et al. 2005, Ekstrand et al. 2006, Jacobson & Tegner 2007). The most common anatomical locations of soccer overuse injuries are the knee, lower leg, groin, and low back (Lüthje et al. 1996, Söderman et al. 2001, Hägglund et al. 2005, Waldén et al. 2005).

2.4 Gender differences in sports injuries

Generally, patterns of injuries in athletes have been assumed to be more sports-specific than gender-specific. So far, most sports injury studies that have investigated gender differences have focused exclusively on knee injuries (Arendt & Dick 1995, Dugan 2005). To date, only a few sports injury studies have compared acute injury rates (Kujala et al. 1995b) or overall injury rates (de Loës et al. 2000, Sallis et al. 2001) between genders.

Previous studies have found rather similar overall injury rates in men and women (Lanese et al. 1990, Sallis et al. 2001). Controversially some sports and recreation-related injury studies have shown males to have 1.3-4 times higher sports- and recreation-related injury risk than their female counterparts (Conn et al. 2003, Dempsey et al. 2005, Knowles et al. 2006a, Haikonen & Parkkari 2010). Studies have also reported a higher incidence of soccer-related injuries among girls than boys (Elias 2001, Powell & Barber-Foss 2000, Tenforde et al. 2011). However, male athletes have been shown to have a higher risk for severe sports-related injuries than female athletes (Conn et al. 2003).

Despite gender similarity in the overall injury rate, females have sustained more injuries in the hip (Satterthwaite et al. 1999, Sallis et al. 2001), lower leg and shoulder than male athletes, while men have sustained more injuries in the thigh than women (Sallis et al. 2001). In marathon runners, Satterthwaite et al. (1999) noticed that males had 1.6-fold greater risk for hamstring and 1.9-fold greater risk for calf injuries compared to female runners.

de Loës et al. (2000) reported that overall risk of knee injury in 12 sports was significantly higher for males than females (0.52 vs. 0.39). Dugan (2005) reported that female athletes have a higher risk for a knee injury in jumping and cutting sports than male athletes in similar sports. Arendt and Dick (1995) also found that knee injuries were more prevalent among female than male athletes in soccer. Malinzak et al. (2001) proposed that the cause of these gender differences may be that females tend to have increased loads on the anterior cruciate ligament. This loading pattern may increase the ACL injury rate among female athletes.

2.5 Risk factors for sports injuries

Risk factors for acute injuries in soccer (Arnason et al. 2004, Ekstrand et al. 2006, Faude et al. 2006) are well documented. Several studies have investigated the risk factors for overuse injuries in long-distance running (van Mechelen 1992a, Taunton et al. 2002, Taunton et al. 2003, Hreljac 2004, Wen 2007), with special reference to lower extremity injuries (Macera 1992, Rolf 1995, Wen et al. 1997, Hreljac et al. 2000) The risk factors for other sports, such as in swimming, and cross-country skiing are poorly understood. Only a few studies of cross-country skiing (Butcher & Brannen 1998) and swimming (McMaster & Troup 1993) have reported injuries, but usually the risk factors for acute and overuse injuries have not been investigated separately.

The factors hypothesized to contribute to the development of sports-related injuries can be divided into two categories: extrinsic and intrinsic factors. This distinction is commonly made in the literature (Taimela et al. 1990, Rolf 1995, van Mechelen et al. 1996, Bahr & Holme 2003, Murphy et al. 2003, Reinking et al. 2007).

2.5.1 Intrinsic risk factors

Intrinsic factors refer to individual biological and psychosocial characteristic predisposing a person to the outcome of a musculoskeletal injury. Such factors include gender, age, anthropometrics, anatomical factors, training years, injury history, menstrual status, physical fitness, and psychological factors (Taimela et al. 1990, van Mechelen et al. 1996, Bahr & Holme 2003, Murphy et al. 2003, Reinking et al. 2007, Wen 2007).

Many studies have reported that gender is a risk factor for an injury and has some effects on the incidence of injuries. These results are conflicting: in some studies females have been found to have greater risk for an injury (Hosea et al. 2000, Powell & Barber-Foss 2000, Rauh et al. 2006), especially knee injuries (Arendt & Dick 1995), while in others male athletes have been reported to be more injury prone than female athletes (Hägglund et al. 2009). There are also studies that have found no gender difference in injury risk (Baumhauer et al. 1995, Bennell et al. 1996). Women have a lower muscle power and the greater laxity in the joint than men. This may also lead to the injuries among female athletes.

Among runners, older athletes with more experience were less affected by injury (Marti et al. 1988, Taunton et al. 2003). Other studies have found no differences between age and injury rate (Wen et al. 1997, Engebretsen et al. 2010). Runners with more than ten years experience had increased risk for an overuse injury, especially Achilles tendinopathy (Knobloch et al. 2008).

The relationship between body size, height, weight and body mass index (BMI, [kg/m^2]) and risk for an injury is controversial. van Mechelen (1996) reported that BMI was not associated with injury risk. Messier et al. (2008) found, among runners, that greater body weight was related to larger knee joint loading and therefore may be a risk factor for a joint injury. In addition, Thelin and co-workers (2006) reported a greater BMI to increase risk for knee osteoarthritis.

Anatomical factors, e.g., leg length inequality, have been reported to be a risk factor for lower extremity overuse injury among runners (Wen et al. 1997). The role of the range of motion of the joints as a risk for injuries is unclear. Previous injury, e.g., in the hamstring, groin, knee and ankle, have been shown to be a risk factor for an injury in athletes (Walter et al. 1989, Dvorak et al. 2000, Bahr & Holme 2003, Taunton et al. 2003, Arnason et al. 2004, Croisier 2004, Engebretsen et al. 2010).

Among female athletes, menstrual status may influence to the risk for an overuse injury. Vigorous training among female athletes, especially when accompanied by low energy intake may lead to menstrual disturbances (Torstveit & Sundgot-Borgen 2005, Nichols et al. 2006) and increase the risk for injury. Younger age at menarche and a history of irregular menstrual periods are associated with increased risk for stress fracture (Kelsey et al. 2007). Psychological factors and pressures in turn may increase the risk for menstrual disturbances (Brukner & Khan 2006).

2.5.2 Extrinsic risk factors

Sports-related risk factors such as type of sport, exposure, nature of event, and role of opponents and team mates have been reported (van Mechelen et al. 1996, Kujala et al. 2003b). The amount of exposure time has found to be an important risk factor for an injury (van Mechelen et al. 1996). In many studies sudden increased training or running distance (Walter et al. 1989, Taunton et al. 2003, Tenforde et al. 2011) or running volume (Lysholm & Wiklander 1987) has also been shown to be a risk factor for injuries. However, Hreljac et al. (2000) found no differences between distance run weekly between those who had never sustained an overuse lower limb injury attributed to running and those that had sustained at least one overuse injury attributed to running.

Training errors without enough resting and recovery time and fatigue are one of the most important risk factors for an athlete (Taimela et al. 1990, van Mechelen et al. 1996). In team sports, especially in soccer, contact situations present risk for an injury (Faude et al. 2006). Injuries are more prevalent in soccer matches compared to training in both men and women (Faude et al. 2005, Hägglund et al. 2009). Equipment, such as shoes, skies and poles, can also be a risk factor for an injury. However, Butcher and Brannen (1998) found no relationship between equipment and the occurrence of injuries. Training surface has been found to be associated with injury risk (Wen 2007). A hard training surface increases the risk for stress fractures (Laker et al. 2007). Knobloch et al. (2008) reported that sand increased the relative risk for mid-portion Achilles tendinopathy by tenfold, while asphalt running decreased it. However, Fuller et al. (2007) found no major differences in the incidence, severity, nature or cause of match injuries between playing on natural grass or on artificial turf by either male or female soccer players. In addition, climate may play a role in the susceptibility to an injury (Taimela et al. 1990).

2.6 Sports career termination due to injury

Injuries can in severe cases terminate an athletic career in sports. The definition of ending a sports career has been described as ending sport at a level where the athlete has practiced and actively competed (Kleiber & Brock 1992). Studies on sports career termination are few, and have usually focused on the psychological factors rather than the role of sports-specific injuries. Most of the studies concerning the psychological factors are quantitative and concern, e.g., self-esteem and life satisfaction (Perna et al. 1999, Thing 2006, Brown et al. 2009). Studies have also usually focused on either male or female athletes (Drawer & Fuller 2001, Söderman et al. 2002, Thing 2006).

The role of injuries as a reason for ending an athletic career in sports has been little studied. Kettunen et al. (2001) reported that every fifth athlete in a sample of former elite male athletes had terminated their career because of an injury, and in the study by Drawer & Fuller (2001) injuries accounted for as much as 47% of such cases. Nearly half of Finnish ice hockey players reported that one of the reasons for ending their career in sports was an injury (Vuolle 2008). Studies on this issue have mainly concentrated on team sports like soccer

(Drawer & Fuller 2001, Söderman et al. 2002), where severe injuries, such as ACL injuries, are more common (Söderman et al. 2002, Waldén et al. 2011b). There is a lack of studies focusing on athletes who terminate their sports career, and how sports-related injury has influenced this decision.

3 AIMS OF THE STUDY

Despite the many sports injury studies there is limited data comparing injury profiles in sports with differing loading patterns, injury profiles between gender, risk factors for overuse injury and the influence of injuries on career termination in one and the same study.

The main goal of this study was to investigate the consequences of sports injuries in sports with different exercise-loading characteristics. The athletes represented Finnish top-level men and women cross-country skiers, swimmers, long-distance runners and soccer players.

The specific aims of this thesis were:

1. To compare the occurrence of sports injuries and type of acute and overuse injuries, recurrent injuries, and severe injuries between sports (I).

2. To compare the occurrence of sports injuries and types of acute and overuse injuries between the genders (II).

3. To investigate the risk factors for overuse injuries in endurance athletes (III).

4. To describe the injuries which were associated or caused the athletes to terminate their sports career (IV).

4 MATERIALS AND METHODS

Finnish top-level cross-country skiers, swimmers, long-distance runners and soccer players in 2005 - 2006 were recruited to our twelve-month retrospective study. The data were collected with a self-report sports injury questionnaire which was sent to the athletes after each competition season. The study design is shown in Figure 1.

4.1 Athletes

The best Finnish male and female cross-country skiers were drawn from the ranking list of the Finnish Ski Association. The best swimmers over different swimming distances in a 50-m pool in 2005, according to the Fédération Internationale de Natation (FINA) points system, were drawn from the Annual Yearbook of the Finnish Swimming Association (2005). Similarly, all the female and male runners whose personal record in 2005 was better than the C level in one of the running distances from 1 500m to the marathon were drawn from the Annual Yearbook of the Finnish Athletics (2005) and included in to the study. Also, male and female soccer clubs who played in the Finnish Premier league were drawn from the list posted on the Football Association of Finland website (www.veikkausliiga.com). Members of the teams at the beginning of the season were invited to participate. This process yielded 1 200 top-level female and male athletes (age 15 - 35 years), representing four different sports and loading modalities, three endurance sports and one team sport. They comprised 300 cross-country skiers, 268 swimmers, 265 long-distance runners and 367 soccer players (21 teams). After excluding participants over 35 years of age and soccer teams with a low response rate, the final study target group consisted of 1 075 athletes (Figure 1).

The study protocol was approved by the Ethics Committee of University of Jyväskylä.

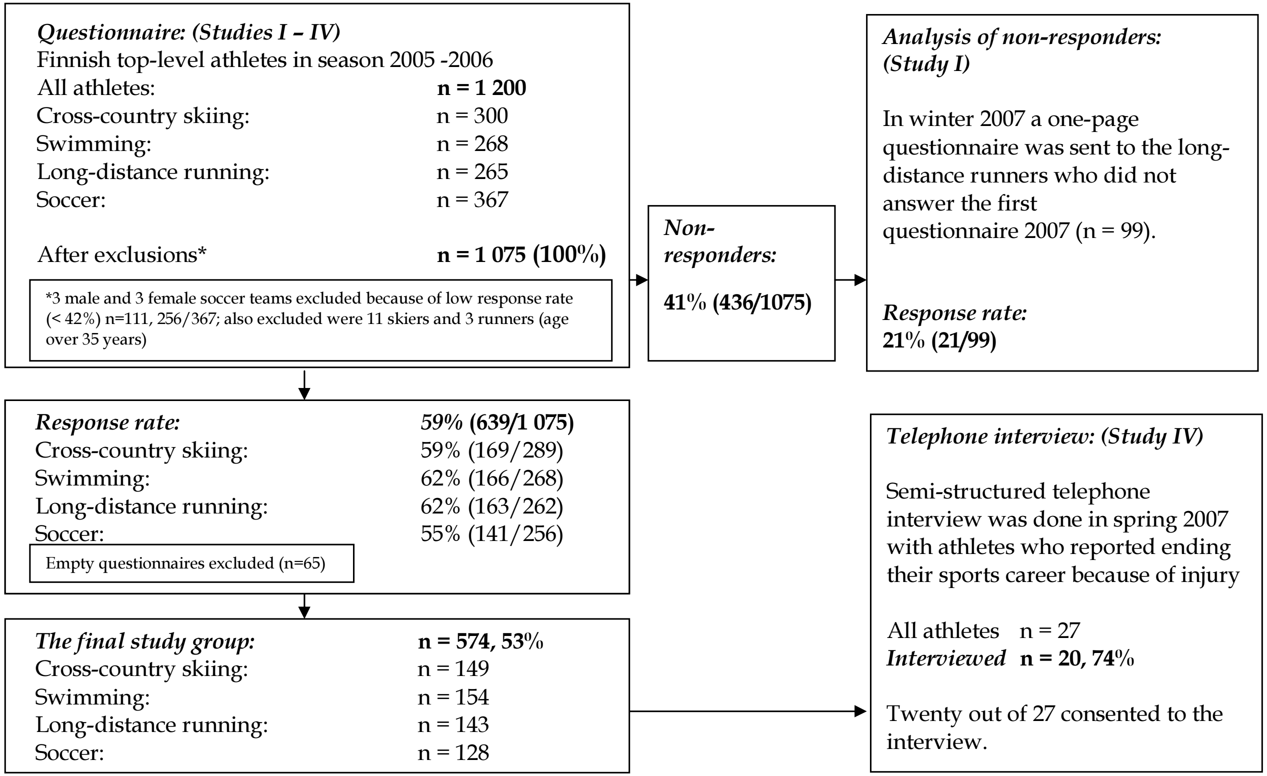

FIGURE 1 The study design.

4.2 Questionnaire

The sports injury questionnaire (21 pages) was mailed to the above-mentioned athlete groups after a competition season (Appendix I). The postal questionnaire also included sports-specific questions (Appendix II). The questionnaire was sent to the cross-country skiers in April 2006, to the swimmers in July 2006, to the long-distance runners in September 2006 and to the soccer players in October 2006. We re-sent the questionnaire after one month to those athletes who did not respond on the first occasion.

4.2.1 Questionnaire (Study I-III)

The questionnaire included items on anthropometry, training history, and training and competition volume. The questionnaire included separate items on training hours and frequency per week during the training and competition seasons as well as on the length of the training and the competition season. On the basis of these six questions, the total number of exposure hours per year was estimated (Appendix I).

The structured questionnaire also asked the athletes for details of up to five of the most severe acute and overuse injuries they had sustained during the past 12 months. In addition, questions were asked about injury location, date of injury, the type of exercise that caused the acute injury and injury-related possible adverse effects on sports performance. Athletes were also asked about the situation (training or competition) in which the injury occurred. The questionnaire included an item about possible previous acute or overuse injuries in the same anatomic location during the past 12 months. The athletes were also asked about absence from training or competition because of acute or overuse injury during the past 12 months. Injury rates are reported as number of injuries per 1000 exposure hours, i.e. hours of any type of exercise, including competitions. Injury rates were calculated separately for acute, overuse and all injuries. Female athletes were also asked about their menstrual cycle. In addition to the questions concerning all athletes there was sports-specific questions. Table 2 shows the basic characteristics of the study group.

This questionnaire had earlier been validated by comparing questionnaire and interview responses after a one-week interval among 54 subjects from different sports. The reliability of the background information questions was excellent: the intraclass correlation coefficient (ICC) varied from 0.96 to 0.99 ($p<0.001$). The reliability of sports and training information was good or excellent (ICC = 0.81 to 0.95, $p<0.001$). The reliability of questions concerning acute and overuse sports injuries during past twelve months varied from moderate to good (ICC = 0.75 to 0.88, $p<0.001$) (Karhula & Pakkanen 2005, Eloranta & Tittonen 2006).

TABLE 2 Characteristics of the study group, means, standard deviations (SD).

	Cross-country skiing n=149		Swimming n=154		Long-distance running n=143		Soccer n=128		All athletes n = 574		
	Male n = 62	Female n = 87	Male n = 71	Female n = 83	Male n = 67	Female n = 76	Male n = 62	Female n = 66	Male n = 262	Female n = 312	All n= 574
Age (years)	24 (4)	22 (4)	19 (3)	18 (3)	25 (5)	24 (5)	23 (3)	21 (4)	23 (5)	21 (5)	22 (5)
Height (cm)	180 (6)	168 (5)	184 (7)	170 (6)	180 (6)	167 (5)	183 (6)	167 (6)	182 (6)	168 (6)	174 (9)
Weight (kg)	74 (6)	59 (65)	79 (8)	62 (7)	67 (7)	54 (5)	79 (6)	62 (7)	75 (9)	59 (7)	66 (11)
Body mass Index (kg/m^2)	23 (1)	21 (1)	23 (2)	21 (2)	21 (1)	19 (1)	24 (1)	22 (2)	23 (2)	21 (2)	22 (2)
Starting training (age)	7 (3)	8 (3)	8 (2)	8 (2)	12 (4)	13 (6)	6 (2)	8 (2)	8 (3)	9 (4)	9 (4)
Training years (at least 2 times/week)	13 (4)	11 (5)	10 (3)	10 (3)	12 (5)	9 (5)	15 (4)	13 (4)	12 (4)	10 (4)	11 (4)
Exposure hours per year (hours/year)	608 (162)	532 (143)	784 (345)	752 (308)	568 (288)	541 (227)	632 (266)	493 (146)	650 (286)	580 (237)	613 (263)
Skiing (km/year)	3627 (982)	2503 (876)									2995 (1077)
Swimming (km/year)			1436 (656)	1562 (685)							1501 (672)
Running (km/year)					3843 (1763)	2618 (1355)					3216 (1678)

4.2.2 Analysis of non-responders (Study I)

To investigate the reasons for non-response, in winter 2007, four months after the postal questionnaire, we sent a further one-page questionnaire to the long-distance runners (99 athletes) who had not responded to the former. The questionnaire contained three questions. The first two questions asked whether the athlete had sustained an acute or an overuse injury during the past twelve months and, if so, how many. The last question concerned the reason not for responding the first postal questionnaire. The most commonly reported reason for non-response was the length of the questionnaire.

4.2.3 Telephone interview (Study IV)

Seven to eleven months after the first questionnaire, in spring 2007, a semi-structured questionnaire interview was carried out with athletes who, in the postal questionnaire, had reported terminating their sports career because of injury in (n=27). Twenty (74%) gave permission for a telephone interview (Appendix III).

The interview included structured and open questions. The injury that had influenced the athlete's decision to end the sports career was studied as well as possible non-medical reasons. Detailed information on the injury which had caused them to end the sports career was asked and also what kind of treatment and rehabilitations they had received, what disabilities, if any, the injury had caused in their life, and whether they still exercised and on what level (Appendix III).

4.3 Sports injury types and sports career termination

The term acute injury was defined as an acute sports injury occurring suddenly or accidentally, interrupting the exercise or the competition of the athlete, or causing an identifiable trauma. An acute injury is any physical injury that keeps the athlete away from at least one training session, or competition, or needs a physician's care (Söderman et al. 2001, Orchard & Seward 2002). The term overuse injury was defined as an injury that causes pain during exercise loading without any noticeable external cause of injury. The injury gradually causes worsening pain during or after exercise. Pain becomes worse when loading is continued and may prevent exercise completely (Brukner & Bennell 1997, Beck 1998).

A recurrent injury was defined a repeat of an acute or overuse injury that had been sustained in the same part of the body prior to embarking on the sports career. Time loss was defined as the time athletes were not able to participate in training or competitions or the time the athlete needed for medical care. Both acute and overuse injuries were classified into three different categories: *minor injury,* involving no time loss, 1-3 days time loss, 4-6 days time loss; *moderate injury,* involving 1-3 weeks time loss; and *major injury,* involving over 3 weeks but less than 3 months time loss, over 3 months but less than 6 months time loss, and over 6 months time loss.

The term "sports career termination" was defined as ending a career in sports at a level where the athlete has practiced and actively competed (Kleiber & Brock 1992). The sports career was considered ended, including where the athlete continued to participate in the same sports, but at a lower level (less targeted), or if the athlete had changed sports.

A menstrual irregularity was defined as 6 menstruations or less per year or totally missing menstruation (Bennell & Alleyne 2006).

4.4 Statistical analysis

Statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS), version 13.0 (study I), version 15.0 (study II – III), and with PASW Statistics, version 18.0 (study IV) (SPSS Inc., Chicago, Illinois, USA). Frequencies, proportions, mean and standard deviations (SD) were used as descriptive statistics. Pearson chi-square statistics, t-tests and analysis of variance were applied to calculate statistical differences in distributions between the different sports. $p \leq 0.05$, two-tailed was considered a statistically significant threshold.

Study I

In the post hoc between-group comparisons, the Bonferroni correction was used, and 95% confidence intervals (CI) of the percentages of injuries were calculated with Confidence Interval Analysis software (CIA, University of Southampton, United Kingdom).

Study II

Analysis of variance (ANOVA) was applied to calculate statistical differences in gender distributions and between different sports. Poisson regression was used to calculate the sports-adjusted injury risk between genders. The associations were expressed using relative risks (RR) and their 95% confidence intervals (CI).

Study III

Analysis of variance (ANOVA) with sex and sports as covariates in the between-sports analysis and gender as a covariate in the within-sports analyses was used to compare athletes without and with tendon, joint, muscle or all the other overuse injuries identified. The results of the analyses of the risk factors for injuries were adjusted for gender and sports (covariate-adjusted) except for the risk factors within each sports, which were as adjusted only by gender, and menstrual status, which was adjusted only by sport. Logistic regression models were used to analyze the association between covariates and injuries. Gender and sports were used as covariates in all the logistic regression models. When investigating the risk factors for injuries between the different sports, swimming was used as the reference sport in all the logistic regression models, except for injuries to the upper extremities, where the corresponding reference sport was running. The associations were expressed using odds ratios (OR) and their 95% confidence intervals (CI). From a clinical point of view, we categorised the significant training-related risk and supportive factors for an injury.

Study IV

Structured questions were analysed by using descriptive statistics such as frequencies, proportions, means and standard deviations (SD). The non-structured questions from the interview were analysed descriptively.

5 RESULTS

The questionnaire was returned by 59% of the cross-country skiers, 62% of the swimmers, 62% of the runners, and 55% of the soccer players. The final study group, with a completed questionnaire, consisted of 149 (52%) cross-country skiers, 154 (58%) swimmers, 143 (55%) long-distance runners, and 128 (50%) soccer players (Figure 1, see page 35). The proportion of females was 54% (n=312) and that of males 46% (n=262). There were differences in age between the responders and non-responders both among the cross-country skiers (23 years [y] vs. 24 y, p=0.024) and swimmers (19 y vs. 20 y, p<0.001), but not among the long-distance runners (both 25 y, p=0.85) or soccer players (both 22 y, p=0.29). No differences were observed between responders and non-responders in success according to the national ranking lists for the year 2005.

Reported mean exercise exposure time during the previous twelve month was greater among the swimmers (767 exposure hours per year [h/y]) than cross-country skiers (564 h/y, p<0.001), long-distance runners (554 h/y, p<0.001), or soccer players (560 h/y, p<0.001). Specific training information for the male and female athletes in the different sports is given in Table 2 (see page 37) and other data, e.g. warming up and other exercises, are given in Table 3.

5.1 Profile of sports injuries (I)

5.1.1 Acute injury

Two hundred and twenty-five athletes (39%, n=225) reported at least one acute injury, and a total of 432 acute injuries. The injury rate among soccer players during past twelve months was higher than that among skiers (73% vs. 28%, p<0.001), swimmers (32%, p<0.001), or long-distance runners (29%, p<0.001). Sixty-seven percent of soccer players with an acute injury had two or more acute injuries. This was statistically higher than the corresponding percentages for cross-country skiers (37%, p=0.001), long-distance runners (44%, p=0.012) or swimmers (49%, p=0.036).

TABLE 3 The proportion of athletes with warming up, cooling down, stretching and other additional exercises.

	Cross-country skiers n(%)	Swimmers n(%)	Long-distance runners n(%)	Soccer players n(%)
Warming up	137 (92)[b]	127 (83)[a,c,d]	134 (94)[b]	124 (97)[b]
Cooling down	144 (97)[b,c,d]	109 (71)[a,c]	123 (87)[a,b,d]	94 (73)[a,c]
Stretching (more than once a week)	128 (86)[b,d]	90 (59)[a,c]	125 (88)[b,d]	89 (70)[a,c]
Additional exercises	74 (52)[c,d]	76 (49)[c,d]	112 (79)[a,b]	85 (70)[a,b]

Superscript indicates a significant ($p<0.05$) mean difference between groups as follows:
[a] significantly different from cross-country skiers; [b] significantly different from swimmers;
[c] significantly different from long distance runners; [d] significantly different from soccer players.

Acute injury rate per 1000 exposure hours was 0.73 among cross-country skiers, 1.01 among long-distance runners, 1.10 among swimmers, and 3.37 among soccer players. When the four sports groups were combined there were no differences in exposure hours between injured and uninjured athletes (mean 589 h/y vs. 628 h/y, p=0.097).

The most typical acute injury of all acute injuries in the cross-country skiers (25%) and soccer players (24%) was the ankle (Table 4). The injury rate in the knee was also significantly higher in soccer players (0.98) compared to skiers (0.22, p=0.048) (Table 5). In the long-distance runners, the most prevalent acute injury occurred to the foot (24%) and, in the swimmers, to the back (18%) (Table 4).

Soccer players had a significantly higher injury rate (3.39) in the lower extremities than swimmers (0.91, p<0.001) and skiers (1.64, p<0.001) (Table 5). In addition, runners (2.68) had a higher injury rate in the lower extremities than swimmers (0.91, p=0.003) (Table 5). Swimmers had a greater number of acute injuries in the upper extremities than cross-country skiers, long-distance runners, or soccer players (Table 4). However, the only difference in the injury rate per 1000 exposure hours in the upper extremities was found between soccer players and long-distance runners

TABLE 4 The number of acute injuries in different anatomical sites by sport.

Anatomical site	Cross-country skiers n=65* n (%)	Swimmers n=87* n (%)	Long-distance runners n=63* n (%)	Soccer players n=194* n (%)
Head, neck, face, eye, tooth	1 (2)	3 (3)	0 (0)	8 (4)
Upper arm, shoulder	1 (2)	14 (16)	0 (0)	5 (3)
Forearm, elbow, palm, wrist, fingers	6 (9)	13 (15)	1 (2)	7 (4)
Thorax, abdomen	4 (6)	1 (1)	3 (5)	3 (2)
Back	11 (17)	16 (18)	6 (9)	9 (5)
Hip, groin, buttock, pelvis	3 (5)	4 (5)	8 (13)	13 (7)
Thigh	6 (9)	5 (6)	6 (9)	33 (17)
Knee	5 (8)	15 (17)	9 (14)	41 (21)
Calf and shin	5 (8)	4 (5)	5 (8)	15 (8)
Ankle	16 (25)	8 (9)	10 (16)	46 (24)
Foot (toes, sole, heel, Achilles)	7 (11)	4 (5)	15 (24)	14 (7)

* Number of acute injuries was 65 in skiers, 93 in swimmers, 67 in runners and 207 in soccer players.
However, only skiers reported the anatomical site for all acute injuries. Swimmers reported 87/93, runners 63/67 and players 194/207 anatomical sites of their injuries.
The proportion of athletes with at least one acute injury: 41 skiers, 49 swimmers, 41 runners and 94 soccer players.

TABLE 5 The acute injury rate per 1000 exposure hours by sport.

Anatomical site	Cross-country skiers Injured n=41 rate	Swimmers Injured n=49 rate	Long-distance runners Injured n=41 rate	Soccer players Injured n=94 rate
Upper extremities	0.31	1.85	0.05[d]	0.26[c]
Upper arm, shoulder	0.05	1.42	0.0	0.15
Forearm, elbow, palm, wrist, fingers	0.26	0.32	0.05	0.11
Back	0.44[d]	0.51	0.30	0.12[a]
Lower extremities	1.64 [b,c,d]	0.91[a,c,d]	2.68 [a,b]	3.39 [a,b]
Thigh	0.24[d]	0.09[d]	0.48	0.67[a,b]
Knee	0.22[d]	0.32[d]	0.53	0.98[a,b]
Calf and shin	0.20	0.10	0.20	0.29
Ankle	0.57[b]	0.21[a]	0.42[d]	0.99[c]
Foot (toes, sole, heel, Achilles)	0.30	0.07[c,d]	0.63[b]	0.33[b]

Anatomical sites between sports were compared by *t* –test.
Superscript indicates a significant ($p<0.05$) mean difference between groups as follows:
[a] significantly different from cross-country skiers; [b] significantly different from swimmers;
[c] significantly different from long distance runners; [d] significantly different from soccer players.

Nearly forty percent (38%) of the injured athletes reported acute muscle cramps or muscle strains. Soccer players (34%) more commonly had contusions than the other sport athletes (runners: 7%, p=0.001; skiers: 17%, p=0.041, swimmers: 18%, p=0.049). Soccer players reported more ligament injuries than swimmers (55% vs. 25%, p<0.001) or long-distance runners (55% vs. 20%, p<0.001). Only soccer players reported injuries to the knee meniscus. The proportion of athletes with at least one acute injury type is shown in Figure 2.

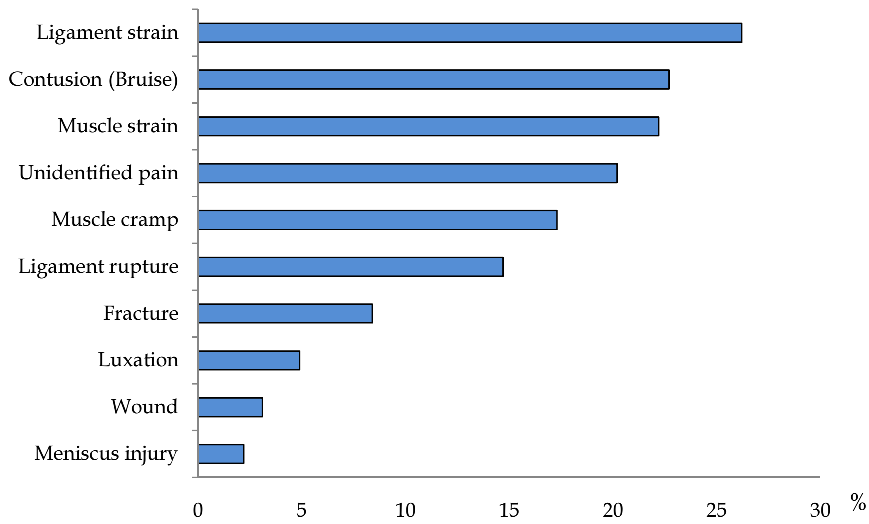

FIGURE 2 The proportion of acute injuries sustained by athletes reporting at least one acute injury (n=225).

Eighty percent of cross-country skiers' acute injuries occurred in a sports (including roller skiing) other than their own sports and over one-third (35%) of them occurred while running. Nearly sixty percent of swimmers' acute injuries (58%) also occurred in a sports other than in their own.

Fifty-three percent of swimming injuries were related to swimming freestyle. Half of runners' acute injuries occurred in running (49%). The most common reason for an acute injury in soccer players occurred in tackling (32%), collisions with other player (23%) and running (21%). In soccer, defenders (33%) and strikers (33%) most commonly reported at least one acute injury during the past twelve months.

Half of the soccer players' (49%) acute injuries occurred during matches, which was more common than in the case of cross-country skiers (17%, p<0.001), long-distance runners (13%, p<0.001) or swimmers (9%, p<0,001).

Most of the acute injuries occurred when playing on either natural grass (52%) or artificial turf (38%). Every second acute injury in soccer (54%) occurred in a contact situation. Soccer players reported equal occurrence of acute injuries in the first and the second half of matches (49%, 51% respectively).

5.1.2 Overuse injury

Two hundred and ninety-two (51%, n=292) athletes reported at least one overuse injury, and a total of 433 overuse injuries. There was no difference in the overuse injury rate between long-distance runners (59%), swimmers (51%) and cross-country skiers (50%) in the past twelve months. However soccer players had a lower overuse injury rate than long-distance runners (42% vs. 59%, p=0.005). The overuse injury rate per 1000 exercise hours was 1.35 in cross-country skiers, 1.48 in swimmers, 1.67 in long-distance runners, and 1.69 in soccer players. Thirty-nine percent of cross-country skiers, 38% of long-distance runners, 35% of swimmers, and 28% of soccer players with an overuse injury had two or more overuse injuries.

The most typical location of all overuse injuries in the long-distance runners, soccer players and cross-country skiers was the foot (41%, 28% and 22%, respectively) (Table 6). Among the long-distance runners with one overuse injury, 20% was located in the Achilles tendon. In the swimmers over 75% with at least one overuse injury had an overuse injury in the shoulder region. Swimmers reported overuse injuries in the shoulder more commonly than cross-country skiers (p<0.001) (Table 6), and the overuse injury rate per 1000 exposure hours in the upper extremities was also higher among swimmers (Table 7). Soccer players had a higher overuse injury rate in the back (0.69) compared to runners (0.18, p=0.011). The injury rate in the lower extremities was higher in soccer players, runners and cross-country skiers compared to swimmers (Table 7).

Nearly fifty percent (47%) of long-distance runners, 41% of cross-country skiers, and 35% of soccer players reported at least one overuse injury in the tendon. Runners had tendon injuries more commonly than swimmers (28%, p=0.011). In swimmers, the most typical overuse injury was a joint injury (34%). A joint overuse injury was more prevalent in swimmers than in cross-country skiers (16%, p=0.011), soccer players (15%, p=0.013) or long-distance runners (13%, p=0.001). The proportions of the different types of overuse injury type reported by all the athletes are shown in Figure 3 (see page 47).

TABLE 6 The number of overuse injuries in different anatomical sites by sport.

	Cross-country skiers n=108*	Swimmers n=117*	Long-distance runners n=128*	Soccer players n=81
Anatomical site	n (%)	n (%)	n (%)	n (%)
Neck region	2 (2)	2 (2)	0 (0)	0 (0)
Upper arm, shoulder	2 (2)	61 (52)	1 (1)	2 (3)
Forearm, elbow, palm, wrist, fingers	8 (7)	7 (6)	1 (1)	1 (1)
Back	18 (17)	17 (15)	7 (6)	16 (20)
Hip, groin, buttock, pelvis	8 (7)	2 (2)	15 (12)	6 (7)
Thigh	5 (5)	1 (1)	10 (8)	8 (10)
Knee	21 (19)	19 (16)	21 (16)	13 (16)
Calf and shin	16 (15)	1 (1)	15 (12)	7 (9)
Ankle	4 (4)	4 (3)	6 (5)	5 (6)
Foot (toes, sole, heel, Achilles)	24 (22)	3 (3)	52 (41)	23 (28)

* Number of overuse injuries in skiers was 110, in swimmers 117, in runners 125 and in soccer players 81.
Skiers reported 108/110 of the anatomical sites of their injuries, runners reported 125 overuse injuries, but 128 anatomical sites.
The proportion of athletes with at least one overuse injury: 74 skiers, 79 swimmers, 85 runners and 54 soccer players.

TABLE 7 The overuse injury rate per 1000 exposure hours by sport.

	Cross-country skiers Injured n=74	Swimmers Injured n=79	Long-distance runners Injured n=85	Soccer players Injured n=54
Anatomical site	rate	rate	rate	rate
Upper extremities	0.27[c,b]	2.07[a,c,d]	0.03[a,b]	0.09[b]
Upper arm, shoulder	0.06[b]	1.82[a,c,d]	0.03[b]	0.04[b]
Forearm, elbow, palm, wrist, fingers	0.21[c]	0.18	0.0[a]	0.04
Back	0.42[c]	0.23	0.18[a,d]	0.69[c]
Lower extremities	2.10[c,b]	0.56[a,c,d]	2.85[a,b]	3.32[b]
Thigh	0.13	0.02[c]	0.19[b]	0.34[b]
Knee	0.55	0.43	0.42	0.58
Calf and shin	0.34[b]	0.01[a,c,d]	0.34[b]	0.42[b]
Ankle	0.11	0.05	0.12	0.29
Foot (toes, sole, heel, Achilles)	0.59[c,b]	0.02[a,c,d]	1.19[a,b]	1.13[b]

Anatomical sites between sports were compared by *t* –test.
Superscript indicates a significant ($p<0.05$) mean difference between groups as follows:
[a] significantly different from cross-country skiers; [b] significantly different from swimmers;
[c] significantly different from long distance runners; [d] significantly different from soccer players.

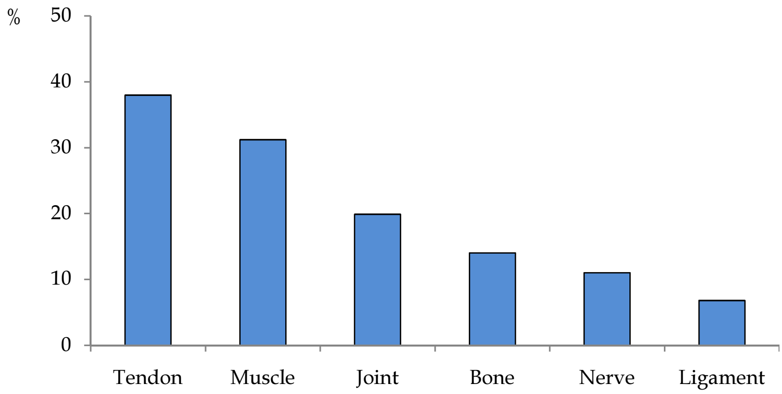

FIGURE 3 The proportions of overuse injuries sustained by athletes reporting at least one overuse injury (n=292).

Over eighty percent (81%) of swimmer's overuse injuries were related to their own sports, and over forty percent (42%) of swimming injuries were sustained in freestyle events. Cross-country skiers reported that 61% of all overuse injuries occurred in sports other than in their own. Among the overuse injuries which occurred in cross-country skiing (n=51), 67% occurred in skiing with the classic technique and 33% in skiing with the skating technique. Overuse injuries of the low back sustained in skiing were more frequent with the classic (59%) than skating technique (12%). Runners whose main distance was over 3000 meters had at least one overuse injury (60%) more often than runners with a distance below 3000 meters (40%, p=0.011).

5.1.3 Severity of injuries

Over half of the acutely injured soccer players (56%) had a major injury and more than 3 weeks lost from training and competition (Figure 4). In ten cases (16%) the injury was so severe that it caused over 3 months' absence from training and competition. Among soccer players, the main reported reason for absence from training and competition over three weeks was an acute knee injury (40%) or ankle injury (24%). Nearly fifty percent (46%) of long-distance runners had a major acute injury (Figure 4), the main site being the foot (47%) and in six out of nine such cases the injury was to the Achilles tendon (67%). In turn, 65% of injured swimmers, and 49% of injured cross-country skiers had only minor injuries (time loss 6 days or less) (Figure 4).

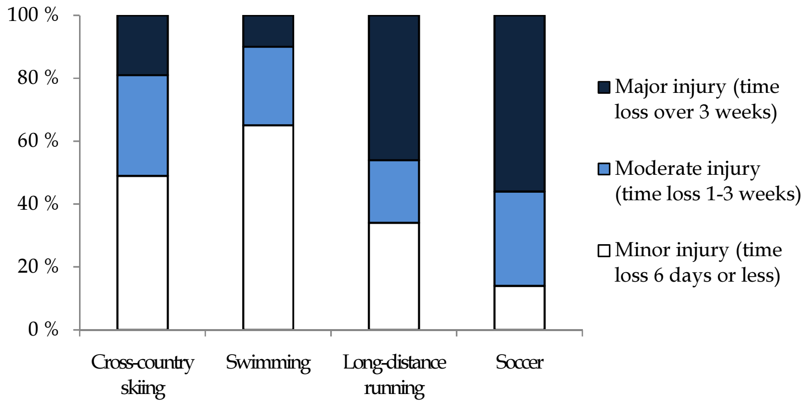

FIGURE 4 Time loss from training and competition by sport among athletes with an acute injury. Soccer players had higher prevalence of major injuries compared to cross-country skiers and swimmers ($p<0.001$), and long-distance runners had higher prevalence of major injuries compared to swimmers ($p=0.004$) and skiers ($p=0.019$).

Soccer players had significantly longer mean loss of time (56 days/year, [d/y]) from training and competition due to an acute injury compared to cross-country skiers (17 d/y, $p<0.001$) and swimmers (56 d/y vs. 12 d/y, $p<0.001$). No difference in time lost was observed between soccer players and long-distance runners (56 d/y vs. 44 d/y, $p=0.35$). However, long-distance runners reported more time loss during the past twelve months than either skiers ($p=0.019$) or swimmers ($p=0.004$).

A similar trend was seen among athletes with an overuse injury. Again, soccer players and runners had longer absences from training and competition compared to skiers and swimmers. Over half of injured runners (52%), and 41% of soccer players had sustained a major injury during the past twelve months (Figure 5). The main reported reason for absence from training and competition was a foot overuse injury, including the Achilles tendon, both in long-distance running (46%) and in soccer (41%). Achilles tendon injury caused the most time lost among runners (20%).

Sixty-six percent of skiers reported only a minor injury (Figure 5). The reported mean time lost from training and competition due an overuse injury was longer in the long-distance runners than cross-country skiers (53 d/y vs. 10 d/y, $p<0.001$), or swimmers (53 d/y vs. 11 d/y, $p<0.001$). No difference in time lost was observed between long-distance runners and soccer players (53 d/y vs. 48 d/y, $p=0.65$). However, soccer players (48 d/y) reported longer mean time lost than swimmers (11 d/y, $p=0.001$) or skiers (10 d/y, $p<0.001$).

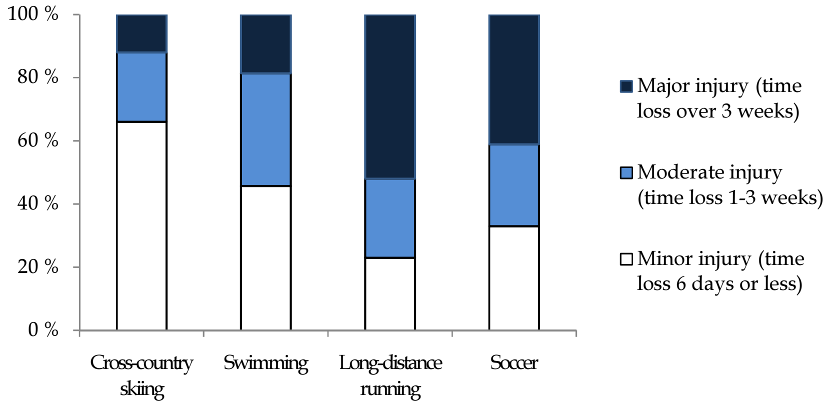

FIGURE 5 Time loss from training and competition by sport among athletes with an overuse injury. Long-distance runners and soccer players had a higher prevalence of major injuries than cross-country skiers or swimmers ($p<0.001$).

5.2.4 Recurrent injuries

Thirty-seven percent of the runners' acute injuries were recurrent. In the cross-country skiers the proportion of recurrent injuries was 42%, in swimmers 43%, and in soccer players 32%. Among the skiers, every third recurrent injury was located in the ankle (30%) or back (30%). Seven out of eight recurrent injuries to the ankle were ligament strains and ruptures. In the swimmers, the most common recurrent injury was located in the back (24%), while, as among the runners, recurrent injuries were also located in the foot (22%) and ankle (22%). In soccer players the most common anatomical site of a recurrent acute injury was the ankle (34%), and 48% of ankle injuries were reported to be ligament strains and 38% ruptures.

Over fifty percent (55%) of the swimmers' overuse injuries were recurrent, mostly located in the shoulder region (59%), and 38% of shoulder injuries were reported to joint injuries. Runners and skiers reported an equal amount of recurrent injuries (37% and 34%, respectively). Among the runners the overuse recurrent injuries were most commonly in the foot (36%) and were usually tendon injuries (82%). Skiers reported overuse recurrent injuries equally to the low back, knee, calf and foot (20%). Twenty percent of soccer players had a recurrent overuse injury. The most common injury site was the back (38%) and the foot (31%).

5.2 Gender differences in sports injuries (II)

During the past twelve months, female athletes trained on average less than men (566 h/y vs. 636 h/y, p=0.002), especially in soccer (445 h/y vs. 584 h/y, p=0.001). However, female athletes, especially in cross-country skiing and long-distance running, did more stretching (80%) than male athletes (71%, p=0.015). Female athletes also did additional exercises more often than male athletes (67% vs. 56%, p=0.011), especially the skiers (64% vs. 35%, p<0.001).

Acute injury

A significantly higher proportion of male (92%) than female soccer players (79%, p=0.037) reported at least one injury (acute and overuse together) during past twelve months. The same trend was also seen in long-distance runners, among whom 82% of male and 68% of female runners reported at least one injury (p=0.060). More male than female athletes reported at least one acute injury (44% vs. 35%, p=0.022), and especially in soccer (84% vs. 64%, p=0.010) (Figure 6). However, after acute injuries were calculated per 1000 exposure hours (training and competition hours during year combined), no difference between men (1.53) and women (1.43, p=0.70) was found.

Among the athletes with at least one acute injury we found only a few gender differences in injury location. A higher proportion of female than male athletes had an acute injury in the heel (6% vs. 1%, p=0.045). However, 4% of the male but none of the female athletes had an acute injury in the upper back (p=0.028). Muscle injuries were more common in male than female athletes with at least one acute injury (44% vs. 31%, p=0.048). Female athletes had a higher rate of acute ligament injury than male athletes (46% vs. 33%, p=0.044), and in soccer (71% vs. 42%, p=0.005). The rate of acute injury in the ankle per 1000 exposure hours was significantly higher in female than male athletes (0.86 vs. 0.44, p=0.014), especially among soccer players (1.47 vs. 0.61, p=0.010).

Overuse injury

The only gender difference in overuse injury in the different sports was found in the long-distance runners, where male runners had a higher prevalence of at least one overuse injury than females (69% vs. 51%, p=0.035) (Figure 6). No difference was found between men and women when the proportion of overuse injuries was calculated per 1000 exposure hours (1.31 vs. 1.73, p=0.16).

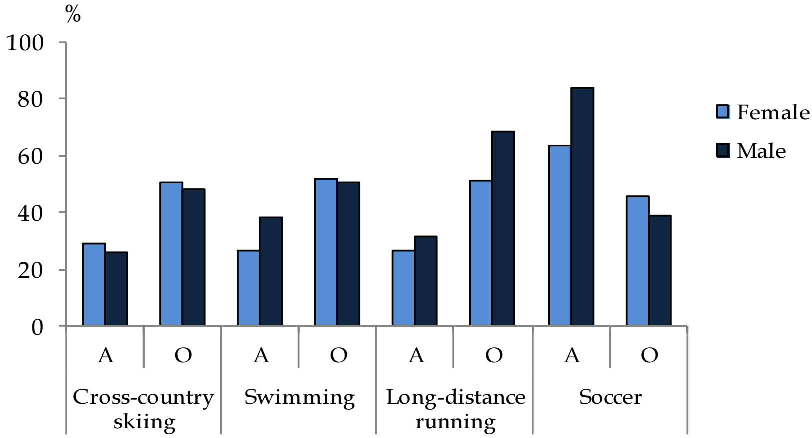

FIGURE 6 The proportions of acute and overuse injuries by sport between male and female athletes (A: at least one acute injury, O: at least one overuse injury). Male runners more often had an overuse injury than females (p=0.035). Male soccer players more often had an acute injury than females (p=0.010).

A higher proportion of male athletes had overuse injuries in the posterior thigh than females (8% vs. 1%, p=0.005), especially soccer players (17% vs. 0%, p=0.020). After adjustment for sports, male athletes were at increased risk for posterior thigh overuse injuries compared to females (RR 5.82, 95% CI 1.28 to 26.39, p=0.022*).* In addition, more males reported toe (4% vs. 0%, P=0.016) and upper back (4% vs. 1%, p=0.036) overuse injuries than females. A higher proportion of female athletes had overuse injuries in the ankle (9% vs. 3%, p=0.032), and wrist (5% vs. 1%, p=0.051) than males. After adjustment for sports, the risk for an overuse ankle injury was greater in females than males (RR 3.05, 95% CI 1.004 to 9.27, p=0.049). Among cross-country skiers, a higher proportion of female than male skiers had overuse injuries in the heel (14% vs. 0%, p=0.035). No gender differences were observed in the proportion of overuse injuries by tissue type. Ankle overuse injuries per 1000 exposure hours were significantly more common in female than male athletes (0.21 vs. 0.04, p=0.024).

When acute and overuse injuries of the ankle and the knee in all sports were combined, no differences were found in the proportion of injured athletes between females (49%) and males (41%, p=0.13), except in female and male soccer players (75% vs 54%, p=0.025).

Menstrual irregularities were reported by 40 (13%) women and these were more common among long-distance runners (26%) than soccer players (6%, p=0.002) or swimmers (6%, p=0.001). Cross-country skiers (16%) reported menstrual irregularities more often than swimmers (6%, p=0.049) and the same trend was seen in soccer players (6%, p=0.072). Athletes with menstrual irregularities more commonly had at least one overuse injury compared to athletes with regular menses (63% vs. 49%, p=0.10). However, among cross-country skiers, a difference in overuse injuries between athletes with regular and those with irregular menses (46% vs. 85%, p=0.010) was found. Females with fewer than 6 menses during past year or no menses at all had a higher prevalence of at least one overuse injury in the lower extremities (92%) compared to females with regular menses (67%, p=0.012).

5.3 Risk factors for overuse injuries among endurance athletes (III)

All overuse injuries

The endurance sports in this study were cross-country skiing, swimming and long-distance running. Athletes with at least one injury were on average one year older than those with no injury (gender- and sports-adjusted means, 22 y vs. 21 y, p=0.013). This was especially evident in long-distance runners (gender-adjusted means 25 y vs. 23 y, p=0.007).

The average number of training camp days (p=0.035) was higher and weekly resting and recovery days during the training season (p=0.006) lower in athletes who had an injury than those without an injury. The covariate-adjusted mean of exposure hours was higher in the athletes with an injury compared to those with no injury (p=0.12). The menstrual cycle had begun on average earlier in athletes with than those without injury (p=0.025). Athletes (gender-adjusted) with low BMI (less than 21) had more overuse injuries in the lower extremities (p=0.015), especially in the foot (p=0.010).

Sports, gender, age, training camp days during the year, and weekly resting and recovery days in the training season were entered into a logistic regression analysis to identify independent predictors for injuries. According to our multivariate model, age increased the risk for an injury (OR 1.06/year; 95% CI 1.01 to 1.11, p=0.022) and the number of weekly resting and recovery days in the training season had a preventive effect (OR 0.66/day; 95% CI 0.44 to 0.995, p=0.047). Odds ratios for all overuse injuries are shown in Table 8 (see page 55).

From a clinical point of view, we also categorised the significant training-related risk and supportive factors for an injury. Risk for an injury was increased in athletes with less than two weekly resting and recovery days during training season (OR 5.16; 95% CI 1.89 to 14.06, p=0.001), and in athletes with over 700 exposure hours during year (OR 2.10; 95% CI 1.21 to 3.61, p=0.008 increased in athletes with more than 12 years of active training (OR 1.67; 95% CI 1.11 to 2.52, p=0.014).

Tendon injuries

Ninety-two athletes (21%, 92/441) had 102 tendon injuries. The most common anatomical sites for a tendon injury were the Achilles tendon (23%), knee region (21%), and shoulder region (15%). The risk for tendon injury was 2.26 -fold (95% CI 1.26 to 4.04, p=0.006) in long-distance runners compared to swimmers. One-fifth of the cross-country skiers had at least one tendon injury.

Athletes with a tendon injury were on average two years older than athletes without such an injury (gender- and sports-adjusted, p<0.001). Exposure hours during the past year were not associated with tendon injuries, but athletes with at least one tendon injury compared to athletes without such an injury on average reported fewer weekly resting and recovery days during the training season (p=0.026). Athletes with a tendon injury had started their sporting career one year later (p=0.049), but reported more years of active training (p=0.003) than athletes without such injury. The number of kilometres run during the past year were not associated with a tendon injury when runners with or without a tendon injury were compared (3331 km vs. 3172 km, p=0.61). Athletes with lower BMI had more tendon injuries than athletes with higher BMI (p=0.004).

Odds ratios for tendon overuse injuries adjusted by sport, gender and age are shown in Table 8 (see page 55).

Joint injuries

Fifty-nine joint injuries occurred in 50 athletes. In half of the runners (6/12) and over forty percent (6/13) of the skiers, the joint injury occurred to the knee. In swimmers, nearly sixty percent (20/34) of joint injuries were in the shoulder region. Athletes with a joint injury on average reported a lower number of competitions than athletes without a joint injury (p=0.013). The mean number of kilometres swum during the past year was higher in swimmers with at least one joint injury than in swimmers without such an injury (1750 km vs. 1437 km, p=0.031).

Sports, gender, age, BMI, exposure hours during a year, and number of competitions were entered into a logistic regression analysis to identify independent predictors for joint injuries. The number of competitions during the past year was a preventive factor for a joint injury (OR 0.95/unit decrease; 95% CI 0.91 to 0.0995, p=0.029). Specific odds ratios are shown in Table 8 (see page 55).

Athletes with a BMI higher than 21 were more prone to a joint overuse injury (p=0.001) than athletes with a BMI lower than 21. There was also a trend towards more low back overuse injuries among athletes with higher BMI (p=0.064).

Muscle injuries

Eighty-nine muscle injuries occurred in 75 athletes (17%, 75/441). The most common anatomical sites for a muscle injury were the shin and calf combined (25%), low back (20%) and shoulder region (20%). Nearly sixty percent (58%) of swimmers' muscle injuries were in the shoulder region, while both runners and skiers had the most shin and calf muscle injuries (39%, 33%, respectively). Low back muscle injuries (30%) were also common among skiers. Athletes with a muscle injury were slightly heavier than those without a muscle injury (covariate-adjusted mean 67 kg vs. 65 kg, p=0.052), and a tendency (p=0.064) for athletes with a lower BMI to report a muscle injury was found.

Sports, gender, age and weight were entered into a logistic regression analysis to identify the risk factors for muscle injury. The only risk factor found for a muscle injury was weight (OR 1.04/kg increase, 95%CI 1.001 to 1.08, p=0.043). The odds ratios are shown in Table 8 (see page 55).

5.4 Sports career termination due to injury (IV)

Fifty-two athletes (9%, 52/548) reported to terminating their sports career. The proportion of athletes ending their career was higher among females than males (13%, 40/304 vs. 5% 12/244, respectively, p<0.001). Of the athletes who had ended their sports career, over forty percent (42%) were swimmers, 23% long-distance runners, 19% soccer players, and only 15% cross-country skiers (Figure 7). In soccer, all the athletes who did not continue playing were female.

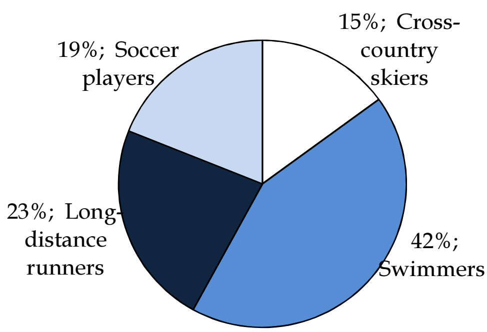

FIGURE 7 The distribution of athletes ending their careers because of injury by sport (n=52).

Fifty out of the 52 athletes gave a reason for termination. Over half (54%) had terminated their sports career because of an injury.

TABLE 8 Odds ratios for risk factors for overuse, tendon, joint and muscle injuries.

	Adjusted for sports			Adjusted for sports and gender			Adjusted for sports, gender and age		
	OR*	**(95% CI)**	**p**	**OR***	**(95% CI)**	**p**	**OR***	**(95% CI)**	**p**
Overuse injuries									
Active training years	1.04	(0.98 to 1.09)	0.065	1.04	(0.99 to 1.09)	0.087	1.01	(0.95 to 1.08)	0.744
Exposure hours (hours/year)	1.001	(1.000 to 1.002)	0.045	1.001	(1.000 to 1.002)	0.051	1.001	(1.000 to 1.002)	0.048
Training camp days (n/year)	1.01	(1.002 to 1.02)	0.017	1.01	(1.002 to 1.02)	0.022	1.01	(1.002 to 1.02)	0.020
Resting days per week#	0.61	(0.41 to 0.90)	0.012	0.61	(0.41 to 0.91)	0.016	0.60	(0.41 to 0.90)	0.013
Resting days per week†	0.76	(0.57 to 1.02)	0.068	0.77	(0.57 to 1.03)	0.076	0.76	(0.57 to 1.02)	0.070
Tendon injuries									
Active training years	1.07	(1.001 to 1.13)	0.046	1.08	(1.009 to 1.15)	0.026	1.07	(0.98 to 1.17)	0.146
Joint injuries									
Starting training (years)	1.10	(1.01 to 1.20)	0.029	1.10	(1.01 to 1.21)	0.028	1.08	(0.99 to 1.19)	0.084
Competitions (n/year)	0.94	(0.89 to 0.98)	0.007	0.93	(0.89 to 0.98)	0.006	0.94	(0.89 to 0.99)	0.011
Muscle injuries									
Height (cm)	1.01	(0.98 to 1.05)	0.385	1.04	(0.97 to 1.09)	0.076	1.04	(0.99 to 1.09)	0.085
Weight (kg)	1.02	(0.99 to 1.05)	0.245	1.06	(1.01 to 1.11)	0.015	1.07	(1.02 to 1.12)	0.009

*OR (Odds ratio), 95% CI (95% Confidence Interval)
Resting and recovery days during training season, † Resting and recovery days during competition season

Eleven athletes reported total 18 acute injuries as the main or contributory reason. Half of the acute injuries occurred to the knee, and were severe ligament injuries and contusions. Another common injury was an ankle ligament injury. Fourteen athletes reported 20 overuse injuries as the reason for ending their career. The overuse injuries were located mainly in the shoulder region (30%) and in the knee region (25%), and were mainly joint injuries.

Athletes who reported to ending their sports career because of injury were an average two and a half years older (24 y vs. 22 y, p=0.006) than those who continued the sport. The incidence of acute (2.96 vs. 1.41, p=0.015) and overuse injuries (2.76 vs. 1.36, p=0.015) per 1000 exposure hours in athletes who ended their career was higher than in the ones who continued their career. However, no difference in mean exposure hours between athletes who continued and athletes who terminated their sports career was found (617 h/y vs. 622 h/y, p=0.92). Athletes who ended their sport reported fewer competitions during the past year (13 vs. 23, p<0.001) and fewer training camp days (9 vs. 21, p=0.008) than athletes who continued their sports career. Athletes who ended their career reported slightly more time away from training and competitions because of an acute injury (66 d/y vs. 34 d/y, p=0.055) and significantly more because of an overuse injury (83 d/y vs. 27 d/y, p<0.001) than athletes who continued in their sport. Most of the athletes who terminated their sports career (70%, 19/27) reported that the injury caused mild or moderate permanent disability.

Telephone interview

Twenty out of 27 athletes gave permission for a telephone interview (Figure 1, see page 35). Eleven of the 20 athletes had stopped their sports career completely and four had made a come-back in the same sports at a lower level. Five of the twenty athletes (25%) were continuing their sports career on the same level as earlier. Two of them had only minor injuries and three had undergone surgery and recovered well enough to be able to continue their sports career. Altogether, fifteen athletes (12 female, 3 male; 3 cross-country skiers, 5 swimmers, 3 long-distance runners and 4 soccer players) were interviewed in more detail.

All the swimmers who ended their career had a shoulder injury. The diagnoses of the shoulder injury were various (i.e. fracture/luxation, nerve compression). All the soccer players who had ended their career were female and had an acute knee ligament injury. Three of them had an ACL injury in both knees. Among the cross-country skiers, the main reason to end the career was a stress fracture in the shin or hip region. In long-distance runners, the injuries were occurred mainly to the knee or low back. The reasons were recurrent knee menisci injury and patella luxation. In addition to the injury, other reasons such as studying, lack of motivation and pregnancy influenced the decision to end the career. In twelve athletes, a severe acute or overuse injury caused a loss of time from training and competition of over 30 days, with a mean of 132 d/y (range 30-270 days).

6 DISCUSSION

Our twelve-month retrospective study was designed to investigate injury profiles among Finnish top-level athletes in four sports with different exercise-loading characteristics (cross-country skiing, swimming, long-distance running, and soccer). The study was carried out with a postal questionnaire (Appendix I, II) sent after the competition season and asking about training habits and possible injuries during the past twelve months. A telephone interview (Appendix III) was conducted seven to eleven months after the postal questionnaire with athletes who reported having ended their sports career because of injury.

Strengths and limitations

The designs of the different sports-related injury studies differ, which renders comparison between studies difficult (Westlin 1976, Sandelin et al. 1980, Renstrom & Johnson 1989, Hunter 1999, Junge & Dvorak 2000, Taunton et al. 2003, Maffulli et al. 2005, Brooks & Fuller 2006). In seeking to determine the etiology of injuries and possible means of injury prevention, it seems crucial to draw a distinction between acute and overuse injuries. In addition, sports-specific analyses are needed to determine the specific risk factors for the injuries typical to individual sports in order to help in their prevention.

Our study used retrospective self-reports to document injuries, as it is very difficult to organize a prospective standardized nation-wide survey to cover a range of individual sports, along with a standardized examination conducted by a physician and standardized recording of the risk factor for all the separate injuries. Our data-gathering methodology means that some limitations need to be kept in mind when interpreting the results. First, some suspected risk factors for injuries are difficult or impossible to study with a postal questionnaire. Secondly, retrospective survey studies suffer from two main categories of recall bias: memory decay, which means loss of information due to failure to recall the event, and the telescoping effect, which is the tendency to remember events in the past as if they occurred closer to the present than they actually did (Harel et al. 1994).

In their review, Walter and Hart (1990) concluded that retrospective surveys are less likely to provide accurate incidence data because of they rely on athletes' responses and thus on diagnoses that lack verification by a physician. Junge and Dvorak (2000) found that the one-year incidence of injuries reported retrospectively was significantly lower than that documented on the basis of weekly follow-up examinations. However, in their methodological study on skiing and snowboarding injuries, Flørenes et al. (2011) found that retrospective athlete interviews was the best method to detect injuries sustained during one World Cup season better than prospective registration by team medical staff. Gabbe et al. (2003) in turn reported both overreporting and underreporting in a self-report survey. In particular, minor injuries may have been underreported. Also, according to Gabbe et al. (2003), recall accuracy declines as the level of detail requested increases. The exact diagnosis of an injury can be difficult. In the present study memory bias with respect to an injury type or diagnosis is possible. Therefore we did not analyse injuries more specifically. It is also difficult for athletes to separate different types of injuries, such as a joint, a ligament, a muscle or a tendon injury. However, while there may be limitations on the accurate recall of injuries, athletes tend to have close relations of co-operation with physicians regarding their medical problems, and also know about more their injuries than other laymen.

Moreover, our questionnaire was validated and its reliability found to be accurate when evaluated against interview data (see methods, page 34) (Karhula & Pakkanen 2005, Eloranta & Tittonen 2006). Questions which were accurate or unclear were not used. Our questionnaire was also sent immediately after the competition season, while elite athletes usually keep a training diary, which can be expected to improve the accuracy of the questionnaire data collection. Further, ending a sports career is such a "big thing" in an athlete's life, that it is reasonable to assume that the athlete can accurately remember the possible injury in question. A further strength in studying athletes who ended their sports career was the use of a telephone interview by semi-structural questionnaire, which gave additional and more specific information about the reasons for termination.

The response rate was low, although comparable to other retrospective epidemiological sports injury studies (Maffulli et al. 2005, Rauh et al. 2006). One reason for the low response rate may have been the length of the questionnaire, which was 21 pages long. Long-distance runners responded to their one-page questionnaire that its length was the main reason for non-response. The somewhat low response rate of the soccer players might be due to the fact that we sent the questionnaire after the competition season, when the members of each team were having a break from training and competition. However, to avoid using biased data, we excluded the teams with a low response rate.

The athletes who participated in the study were on a high competitive level. In this respect, it was reasonable to compare different types of sports. Also, the method was the same for all the sports studied, and each sport was represented by nearly same number of athletes. In addition, no association between position in the ranking list and response rate was found between responders and non-responders. Admittedly, we do not have exact knowledge on whether those who did not respond had fewer injuries; however, but this possible selection bias should be rather similar in all sports.

6.1 Profiles of sports injuries

The number of subjects with at least one acute injury was highest in the soccer players. Half of the acute injuries occurred during matches. Earlier studies have found a high prevalence of injuries sustained during matches (Faude et al. 2005, Hägglund et al. 2009). Incidence of the overuse injuries was highest in the long-distance runners. Interestingly, among cross-country skiers both acute and overuse injuries occurred mainly in sports other than their own event. This has been reported earlier for overuse injuries (Orava et al. 1985), but not for acute injuries. The acute injuries of the swimmers occurred mainly when practising another sport, while their overuse injuries occurred mainly when swimming. This is in the line with earlier studies on acute injuries (Baxter-Jones et al. 1993) and overall injuries (Wolf et al. 2009), although acute and overuse injuries have not usually been differentiated or the type of training context specified.

Swimmers had more acute and overuse injuries in the shoulder region than the athletes in the other sports. In turn, a high proportion of acute and overuse injuries were located in the lower extremities in cross-country skiers, long-distance runners and soccer players. Among skiers and runners the main acute and overuse injury location was the foot, including the Achilles tendon. Type of loading was strongly associated with the anatomical location of an overuse injury, as shown by the difference in shoulder injury incidence between swimmers and cross-country skiers. In our study, the proportions of shoulder injuries in cross-country skiers were much lower than has been reported earlier (Smith et al. 1996).

Cross-country skiing

According to the review by Smith et al. (1996), the incidence rate of injuries in skiers has varied from 0.5 to 5.6 injuries per 1000 skier-days. In our study, the acute injury rate among skiers was counted in exposure hours, and was lower than in an earlier Finnish population-based study, where it varied from 1.3-2.2 per 1000 exposure hours (Haikonen & Parkkari 2010). Because of methodological differences, our incidence rate cannot be directly compared to the earlier results, but it can be compared to the rates in the other sports included in our study. Our acute and overuse injury rate per 1000 exposure hours in skiers was lower than in the other sports. Also both acute and overuse injuries originating in their own event were rare in skiers. Our findings are in accordance with earlier findings (Sandelin et al. 1980, Orava et al. 1985, Renstrom & Johnson 1989).

Acute and overuse injuries in skiers occurred mainly in the lower extremities. The most common acute injury was in the ankle. Smith et al. (1996) reported that the most common location of traumatic injuries was in the knee and the second most common in the ankle. However, in our study, ankle injuries were three-fold compared to knee injuries. In skiers, ankle injuries may be common due to training for a sports other than their own, such as running. We found only a few skiers with an injury in the shoulder region, although the shoulders are intensively load during skiing. In contrast, Smith et al. (1996) reported that every third of skiers' upper extremity injuries occurred to the shoulder. They also reported that every third of skiers had an acute injury in the upper extremities; such injuries were observed in only eleven percent of our sample of skiers. Two-fifths of our athletes' acute injuries were ligament injuries, sprains and strains; this finding is in line with Smith et al. (1996).

Orava et al. (1985) reported that the most common overuse injury among skiers was the foot in addition to the back and knee. In our study, the skiers had at least one overuse injury usually in a tendon or muscle. In Orava et al. (1985) the most prevalent injury types occurred in bone and muscle.

In cross-country skiing two dissimilar techniques are used. In particular, the skating technique, with increased velocity and novel equipment, may increase the number of injuries (Butcher & Brannen 1998). The literature exhibits conflicting opinions regarding the injury rate linked to the skating and classic techniques in cross-country skiing (Eriksson et al. 1996, Butcher & Brannen 1998, Bahr et al. 2004). In our study, overuse injuries of the low back were significantly more frequent when skiers were using the classic technique. Due to low number of the acute and overuse injuries in the cross-country skiers tht originated in their own event, we did not have enough statistical power to study the possible effect of skiing style on the injury rate in more detail.

Swimming

Over thirty percent of our swimmers had at least one acute injury, which is in line with earlier findings (Baxter-Jones et al. 1993, Maffulli et al. 2005, Wolf et al. 2009). As in Baxter-Jones et al. (1993), our swimmers' acute injuries occurred more often in another sports than their own main event. The same trend was seen in the study by Wolf et al. (2009) where nearly 40% of overall injuries were the result of other activities. In Wolf et al. (2009) the overall injury rate of collegiate swimmers, including both men and women, were 3.9 injuries per 1000 exposure hours. In our swimmers the injury rate was smaller (2.6 injures per 1000 exposure hours). The differences may due to the different definitions used. An exposure was defined in Wolf et al. (2009) as participation in one game, one practice, strength training, or conditioning session, or one cross-country activity, whereas we combined annual exposure hours from reported training hours per week in training and competition seasons.

The most common acute injuries were located in the back, knee, and shoulder region. As expected, swimming injuries commonly were localised in the upper extremities, especially in the shoulder region. Similarly, earlier studies have reported a shoulder injury among every third swimmer with a swimming-related injury (McMaster & Troup 1993, McMaster et al. 1998, Wolf et al. 2009). Larger proportions of shoulder injuries and pain have also been reported (Richardson 1987). The differences in numbers may be due differences in methods and definitions of injuries. Bak et al. (1989) investigated shoulder pain over one year, as in our study, while McMaster and Troup (1993) and McMaster et al. (1998) reported current shoulder pain. In the study by McMaster and Troup (1993), athletes were asked if they had ever had shoulder pain.

The considerable incidence of an overuse injury in the shoulder is understandable because a swimmer performs more than one million strokes annually with each arm. In addition, almost all of the propulsive force comes from the upper extremities. Incorrect biomechanics, errors of technique and the large number of repetitive movements can cause microtrauma to structures in the shoulder, and thus influence the occurrence of overuse injuries (Richardson 1987, Pink & Tibone 2000). Studies have proposed that overuse may lead to instability and impingement of the shoulder (Allegrucci et al. 1994, McMaster et al. 1998, Pink & Tibone 2000, Weldon & Richardson 2001). In addition, a high shoulder range of motion can decrease stability of the glenohumeral joint, along with muscular imbalance, which has been suggested to be important factor in the development of an overuse injury (McMaster et al. 1998, Weldon & Richardson 2001). However, a swimmer has to have a good flexibility to be able technically to perform the best movements in the water. Limitations in the range of motion may prevent a swimmer from swimming as efficiently as possible.

Sein et al. (2010) found only a minimal association between laxity and shoulder impingement, but reported supraspinatus tendinopathy as a major cause of shoulder pain. However, Sein et al. (2010) found no association between swimming stroke and supraspinatus tendinopathy. In our study, only one-fourth of shoulder injuries was reported in the tendon; instead, more injuries were reported in the joint of the shoulder region. Because our study was conducted with a self-report questionnaire, the range of movements, exact diagnosis of the injury, the differences between tissue types and the specific location of e.g. tendon injuries could not be determined. In swimming and skiing, the upper extremities are predisposed to repetitive loading, but, interestingly, overuse injuries in the upper extremities were common only in swimmers and were sustained while swimming. This is probably related to the over-head movements in the water made by swimmers. The next most common overuse injuries in swimmers were located in the back and knee. Earlier studies have reported that overuse injuries in the above-mentioned sites are due to a large amount of swimming training, especially in the butterfly and breastroke (Richardson 1987, Ferrell 1999, Rodeo 1999). A poor swimming posture in the water may also contribute to musculoskeletal back injury (Ferrell 1999). In our swimmers, unidentified pain was the most common type of acute back pain. Most of the swimmers' acute injuries were minor, and hence it may be that they had not visited a physician and thus not had their injuries diagnosed.

Long-distance running

One-year overall injury incidence among our long-distance runners was in line with those earlier reported for marathon runners (2.5 injuries/1000 exposure hours) by Lysholm & Wiklander (1987). However, Walter et al. (1989) found a greater incidence than we did. In the study by Walter et al. (1989), only 20 percent of competitive runners, usually top-level athletes, had more injuries, and these were due to excessive training. In addition, fitness and recreational runners may have technical errors in running, which may predispose them to injury. In addition, in Walter et al. (1989), the injury rate was not counted per exposure hours. Instead, they gave the injury rate in athletes with at least one injury during the twelve-month follow-up as a percentage. Knobloch et al. (2008) reported an injury rate among running athletes of 0.08 per 1000 km exposure hours over six months. Comparison is difficult because we calculated the injury rate per 1000 exposure hours over a year.

Long-distance running produces a regular pattern of repetitive impacts consisting of moderate ground-reaction-forces (van Mechelen 1992a, Crossley et al. 1999, Hreljac 2004). Earlier studies have shown that anatomical factors, training errors, long training distance per week and rapid impact forces may be reasons for running injuries (Lysholm & Wiklander 1987, Rolf 1995, Murphy et al. 2003, Hreljac 2004, van Gent et al. 2007, Messier et al. 2008). Both acute and overuse injuries were common in the lower extremities among our runners. Previously it has been reported that two-thirds of overuse injuries are located in the knee, lower leg and ankle in long-distance runners (van Mechelen 1992a, Taunton et al. 2002, Taunton et al. 2003, van Gent et al. 2007, Knobloch et al. 2008). Our results for runner's injuries strengthen these findings, especially the predisposition of the foot to an overuse injury because of its repetitive loading while running. However, our runners had a high number of Achilles tendon injuries, as in the study by Knobloch et al. (2008). In agreement with our findings, Rolf (1995) and van Gent et al. (2007) also reported in their reviews that foot problems, including the Achilles tendon, were common in runners. Ankle injuries were also common in our study, as in Rolf (1995). However, van Gent et al. (2007) reported in their review that the ankle was a less common site of lower extremity injury. A high risk for Achilles tendinopathy in former middle- and long-distance runners and tendon rupture in former sprinters (Kujala et al. 2005) and master track and field athletes (Kettunen et al. 2006) has been reported.

Soccer

Soccer generates higher ground reaction forces, applied in different directions, during jumping, landing, starting and stopping compared to distance running (van Mechelen 1992a, Crossley et al. 1999, Hreljac 2004, Nikander 2005) and predisposes players to injuries. Our soccer players had a greater injury rate than skiers, swimmers or runners. Over five acute and overuse injuries (combined) occurred per 1000 exposure hours during one year. Söderman et al. (2001) found the same injury incidence per 1000 soccer hours. In the study by Hägglund et al. (2003) the injury incidence was slightly greater. Two-thirds of the players´ injuries in our study were acute, also shown in earlier studies in both female (Engström et al. 1991, Faude et al. 2005, Hägglund et al. 2009) and male players (Arnason et al. 2004, Hägglund et al. 2009).

Beside quick movements and changes in running direction in the field, contact situations also increase the amount of injuries. Half of all the acute injuries in soccer occurred in matches. Our findings are in line with earlier reports, where 44%-58% of acute injuries have occurred during matches (Kujala et al. 1995b, Faude et al. 2005, Tegnander et al. 2008, Hägglund et al. 2009). In the other sports studied, acute injuries in competitions were rare. Half of our players' acute injuries occurred in contact situations, for example during tackling situations. However, Engström et al. (1991) and Junge et al. (2004b) reported that on average 80% of acute injuries occurred, in physical contact with another player. Risk taking and aggressive behaviours may be one cause of injuries (Engström et al. 1991, Drawer & Fuller 2002). Some acute injuries could also be decreased by following the rules of the game in the field. In our study, in line with the study of Faude et al. (2006), strikers and defenders had at least one acute injury more often than players in the other playing position.

A high incidence of acute injuries (over 80%) in the lower extremities has been reported both in elite female and male players (Engström et al. 1991, Arnason et al. 2004, Faude et al. 2005, Tegnander et al. 2008). Our players, too, most commonly had injuries in the lower extremities. Most of the acute injuries in our players were located in the ankle, knee and thigh, again in line with earlier studies (Söderman et al. 2001, Tegnander et al. 2008). The studies by Arnason et al. (2004) and Hägglund et al. (2009) reported the same trend as in our study concerning the location of acute injuries, except for ankle injuries, the incidence of which was four times lower than in our study. However, in the study by Arnason et al. (2004), injury data were collected prospectively throughout the competition season. Our study also concerned the training season. One-half of our players had at least one acute ligament strain or sprain while other common injury types were muscle injuries and contusions. These three types of injuries have also been found to be common in other studies (Arnason et al. 2004, Hägglund et al. 2009). The overuse injuries of our players were located mainly in the back and the foot. However, groin injuries have been reported to be most common overuse injuries among soccer players (Arnason et al. 2004), especially among male players (Hägglund et al. 2009). Only a few groin overuse injuries were reported by our female and male players. Because we used a self-report questionnaire, it may be that groin injuries had not not been well identified among our athletes. Söderman et al. (2001) also reported that groin overuse injuries were rare in female soccer players.

Severity of injuries

Arnason et al. (2004) found 23% of injuries to be severe and time loss from training and competition in one season because of overall injuries to be over three weeks. Chomiak et al. (2000) and Tegnander et al. (2008) reported that 17% of soccer players' injuries were severe and caused over four weeks time away from the sports. Hägglund et al. (2009) reported an even lower proportion of severe injuries (10%). In our soccer players the corresponding proportions of time lost of over three weeks and over four weeks were much higher for both acute and overuse injuries. The reason may be the high number of acute severe knee and ankle injuries, such as reported by Darrow et al. (2009). In the long-distance runners, time loss was commonly due to overuse injuries of the foot, mainly in the Achilles tendon, causing nearly two months' absence from training and competition. However, they did not terminate their sports career because of the Achilles tendon injury. Although swimmers and skiers had great number of injuries, long-term time loss was rare. This may be due the training program. Soccer players and runners tend mainly to train their own sports, soccer and running. If athletes have an injury in the lower extremities, their modified training and cross-training should be tailored individually to return them as soon as possible to full training and competitions. This is important to avoid loading the injured site and retain the athlete's physical fitness despite the injury. Swimmers can usually continue modified swimming when they rehabilitate their lower extremities. Swimmers also tend to engage in other dry-land cross-training exercises outside the pool, such as muscle training. Skiers also do a lot of training besides skiing, such as running and other endurance exercises, mainly because of lack of snow. These factors may explain swimmers and skiers short absences from training.

Recurrent injuries

We found a previous injury in the same anatomic location in nearly 40 percent of both acute injuries and overuse injuries when all sports were combined. As expected, recurrence of injuries was common in locations where the incidence of new injuries is common. This knowledge is important when rehabilitating injuries in these locations. Recurrent injuries were especially common in swimmers and rarest in soccer players. Previously, the proportion of recurrent injuries in soccer during three seasons has been reported to be over 20% (Hawkins & Fuller 1999). In our study, the proportion in soccer players was nearly 30% and acute recurrent injury was more common than recurrent overuse injury. The difference may be partly explained by methodological differences between the studies. Swenson et al. (2009) found, as we did, that ligament sprains were the most common type of recurrent injury. Many studies on athletes and previous injury as a risk factor for a recurrent injury have been published (Walter et al. 1989, Dvorak et al. 2000, Taunton et al. 2003, Arnason et al. 2004, Croisier 2004, Faude et al. 2006, Hägglund et al. 2006, Wen 2007).

Almost twice as many of our long-distance runners reported a previous injury than runners in an earlier study (Marti et al. 1988). These differences may at least partly be explained by the possibility that training volume among the participants in Marti et al. (1988) may have been lower than in our study. Studies on cross-country skiing and recurrent injuries are lacking. Proper rehabilitation of the first injury and a good training program are needed to prevent recurrent injuries. Proprioceptive training seems to be necessary for both male and female athletes to reduce the risk of recurrent injuries (Hupperets et al. 2009), while limited evidence for a reduction in ankle sprain recurrences through exercises has also been shown (Handoll et al. 2001). In addition, Zech et al. (2009) concluded in their systematic review that proprioceptive and neuromuscular interventions after knee and ankle joint injuries can be effective in the prevention of recurrent injuries and improving joint functionality. However, the small numbers of studies that have reported specific outcomes make the reliability of their conclusions uncertain.

6.2 Gender differences in sports injuries

More male than female athletes had at least one acute injury, and this was especially seen among soccer players. In addition, more male than female long-distance runners had at least one overuse injury. However, we found no differences between gender and the number of acute or overuse injuries per 1000 exposure hours. Only a few gender differences in the anatomical locations of injuries were found. The main difference was a greater number of overuse injuries in the posterior thigh in male than female athletes, whereas females had a greater risk for overuse injuries to the ankle. The risk for such injuries remained after adjustment for sports. Overall, a higher proportion of female soccer players had more combined acute and overuse injuries in the ankle and knee than male players. Among the different sports, female long-distance runners reported more menstrual irregularities than the women in the other sports. However, it was only among skiers that women with irregular menses had more overuse injuries than skiers with regular menses.

Male athletes have been reported to be at increased acute injury or overall injury risk compared to female athletes (Kujala et al. 1995b, Junge et al. 2004b, Knowles et al. 2006a, Darrow et al. 2009, Hägglund et al. 2009). In contrast, Elias (2001) showed greater aggregate injury in female than male soccer players, and Powell and Barber-Foss (2000) reported more acute injuries in girls than boys in high school sports. Increased injury risk in female swimmers (Sallis et al. 2001) and high-school cross-country runners (Rauh et al. 2000, Tenforde et al. 2011) compared to males has been reported, while Sandelin et al. (1980) found that male cross-country skiers had more acute injuries than female skiers. Also, no gender differences in injury rates have been found among swimmers (Wolf et al. 2009). Overall, in accordance with our findings, earlier studies have found no gender differences in overall injury incidence in different sports after adjustment for exposure time (Lanese et al. 1990, Messina et al. 1999, Wolf et al. 2009). It seems that possible gender differences in the proportion of injuries may partly be explained by differences in exposure time.

In a review, van Gent et al. (2007) reported that the overall injury rate in the lower extremities was similar in female and male runners, and the same finding has been reported for cross-country skiers (Sandelin et al. 1980, Orava et al. 1985, Smith et al. 1996) and soccer players (Hägglund et al. 2009, Ekstrand et al. 2011). Acute injuries in the lower extremities were common in our athletes and no gender differences were found. In addition, an equal number of overuse injuries of the lower limbs was found between males and females. In contrast to Satterthwaite et al. (1999) and Sallis et al. (2001), we found no difference between gender and different sports groups in injuries of the calf or hip.

Hamstring strains are common injuries in sports characterized by maximal sprinting, kicking and sudden acceleration (Lysholm & Wiklander 1987, Kujala et al. 1997, Bahr & Holme 2003, Croisier 2004, Hägglund et al. 2009, Ekstrand et al. 2011). Waldén et al. (2005) reported that acute thigh injuries in soccer players were the most common injury, causing a great amount of lost training and competition time. There is evidence to show that previous hamstring strains and age (Arnason et al. 2004, Hägglund et al. 2006, Engebretsen et al. 2010) are independent risk factors for new hamstring strains. Thigh injuries may partly be explained by muscle fatigue, high training intensities, insufficient warm-up and hamstring tightness (Kujala et al. 1997, Bahr & Holme 2003, Croisier 2004), but the evidence for this is less convincing (Bahr & Holme 2003, Arnason et al. 2004). In some cases, where the size of the team is low, many players may be injured at the same time. The consequent high amount of playing time per player may increase the risk for thigh injuries, and the risk for overall injuries. In our study there was no gender difference in acute thigh injuries. However, a higher proportion of our male than female athletes had overuse injuries in the posterior thigh, which is in line with the findings of earlier studies (Satterthwaite et al. 1999, Sallis et al. 2001) and clinical experience.

Hosea et al. (2000) found in ballplayers that females had greater overall risk for ankle injury than males. In our study females had a three-fold greater risk than males for overuse injury in the ankle. Higher joint laxity in females may contribute to this finding. Our female soccer players had slightly more acute ankle injuries than males. Moreover, women had more overuse injuries in the ankle and slightly more overuse injuries in the wrist than men. Methods such as use of insoles, external joint supports and multi-intervention training programs, have been proposed to prevent injuries in these anatomical locations (Parkkari et al. 2001, Aaltonen et al. 2007, Pasanen et al. 2008). Pasanen et al. (2008) concluded that a neuromuscular training programme is effective in preventing acute non-contact leg injuries in female floorball players. Because in our study the incidence of ankle injuries was greater in female than in male athletes, it is especially important for the female athletes to have proper rehabilitation after injury to prevent recurrence of the ankle injury.

Earlier studies have found more knee injuries, especially ACL injuries, among women than men (Arendt & Dick 1995, Messina et al. 1999, de Loës et al. 2000, Malinzak et al. 2001, Dugan 2005, Hägglund et al. 2009, Waldén et al. 2011a). An ACL injury was reported in six cases of which five were women. Due to the low number of these injuries, we lacked the statistical power to investigate this in more detail. Overall, we found a similar number of knee injuries in men and women in all four sports. Haapasalo et al. (2007) also found no gender differences in overall knee injury risk, except in endurance sports. Female soccer players at the time of such an injury have been found to be younger than male players (Bjordal et al. 1997). During the present one-year retrospective study only one male soccer player suffered from an ACL injury, but no age differences were found between the female soccer players who had an ACL injury (22 y) and those who did not (21 y, $p=0.53$). When acute and overuse injuries in the ankle and knee were combined, female soccer players had more such injuries than male players, as has also been found in earlier studies, for both the ankle (Hosea et al. 2000, Elias 2001) and knee (Arendt & Dick 1995, de Loës et al. 2000, Dugan 2005, Hägglund et al. 2009) separately.

In line with earlier studies (McMaster & Troup 1993, Wolf et al. 2009, Sein et al. 2010) on elite swimmers, our swimmers' overuse injuries occurred mostly in the shoulder region without gender differences. Both acute and overuse injuries in the upper back in our female swimmers were rare. Sallis et al. (2001) reported that female swimmers had more injuries in the shoulder and back/neck region than male swimmers. They discussed the possibility that the difference between genders in these injuries may be due differences in training intensity. However, in our study there were no gender differences in exposure hours during the past twelve months.

Female sex has been found to be a risk factor for stress fractures in the military population (Mattila et al. 2007), but this finding is less apparent in athletic studies (Snyder et al. 2006, Laker et al. 2007). Iwamoto and Takeda (2003) concluded in their review that male athletes tend to have more stress fractures than female athletes. The findings on female sex are inconsistent, as Bennell et al. (1996) and Kelsey et al. (2007) found an association between menstrual disturbances and stress fractures among runners, but Sandelin et al. (1980) found no association when studying cross-country skiers. Every fourth female athlete have been reported to have menstrual irregularities (Torstveit & Sundgot-Borgen 2005, Nichols et al. 2006) and these have been more common in long-distance runners, ballet dancers and gymnasts than in swimmers (Burrows & Bird 2000, Nichols et al. 2006). Tenforde et al. (2011) found no association between previous injury and menstrual irregularities among high school runners. Our long-distance runners also had significantly more menstrual irregularities than soccer players and swimmers. However, we did not find any association between stress fractures and menstrual irregularities. We also studied the association between menstrual irregularities and the number of injuries, and after adjustment for exposure hours, we found no association.

We found no great differences between male and female athletes and their sports injuries.

6.3 Risk factors for overuse injuries among endurance athletes

We studied three endurance sports and their risk factors for overuse injuries. In general, on average, athletes with an overuse injury were one year older than athletes without such an injury; especially this was seen among the long-distance runners. Athletes with less than two weekly resting and recovery days in the training season had over five-fold greater risk for an injury. Athletes who had more than 700 annual exposure hours had a two-fold greater risk for an injury.

The role of age as a risk factor for injuries is controversial. Some studies of running or cross-country skiing have shown that injury risk is independent of age (Lysholm & Wiklander 1987, Marti et al. 1988, Tenforde et al. 2011). Sandelin et al. (1980) found male skiers under 30 years to have more injuries than older skiers, and Marti et al. (1988) concluded that with increasing age the incidence of running injury decreased. However, Engebretsen et al. (2010) reported that injured winter sports athletes did not differ in age from non-injured athletes. One reason for this difference maybe because the study group consisted of athletes who participated in the Winter Olympic Games. It is possible that the athletes were rather similar in age. This was unlike our study, where the injured athletes were on average one year older than the non-injured athletes.

Earlier studies have implicated training volume, i.e. volume of running or higher weekly mileage, as a risk factor for injuries (Lysholm & Wiklander 1987, Marti et al. 1988, Wen 2007, Tenforde et al. 2011). In contrast, Hreljac et al. (2000) found no differences in distance run weekly between those who had never sustained an overuse lower limb injury attributed to running and those that had sustained at least one such overuse injury. Similarly, we found no association between injuries and number of kilometres run weekly, but a low number of weekly resting and recovery days and high number of training camp days were associated with higher risk for overuse injury. van Mechelen et al. (1996) found in their study of the general population that high exposure time was a risk factor for overall injury, which is in line with the report by Dvorak et al. (2000) among soccer players. Also, our endurance athletes with high number of annual exposure hours were at increased risk for an injury. In addition, a long history of active training years was a risk factor for an overuse injury. This is understandable in light of our study where older age was a risk factor for such an injury. We found also a tendency to an association between overuse injuries and long running experience.

Because tendon, joint and muscle overuse injuries were the most common types in our athletes, we concentrated on these injuries.

Tendon injuries

Tendon injuries were especially common among long-distance runners with, typically, a low number of resting and recovery days from training. The runners with tendon injuries had on average more exposure hours per year than in the runners without such an injury. Our findings support the hypothesis that overuse injuries are partly caused by excessive training without enough resting and recovery time. However, number of kilometres run was not correlated with tendon injuries. An average of two resting and recovery days per week clearly reduced the risk of injury and there was a statistically non-significant trend that those athletes who had on average one resting and recovery day per week had 15% lower risk of injuries compared to those with less than one resting and recovery day. A high number of active training years was associated with tendon injuries. Our athletes with tendon injuries were older than those without such injuries. Knobloch et al. (2008) also reported that runners with more than ten years experience had an increased risk for Achilles tendinopathy. As also in our study, Marti et al. (1988) reported that overuse injuries in the Achilles tendon were more common in older than younger runners. Age-related degeneration seems to play an important role in the etiology of tendon injuries (Kujala et al. 2005). To avoid injuries, adequate resting and recovery time between training sessions is important for all athletes who are training excessively with repetitive movements, and may be especially important for older athletes with a long training history, especially for athletes with an Achilles tendon injury. Repetitive loading of the tendon within the physiologic range leads to cumulative microtrauma, which may require days or weeks to fully self-repair (Khan et al. 1999). Rehabilitation with exercise alone was found to recover Achilles tendinopathy among the majority of the study group (Silbernagel et al. 2011). Every second athlete in our study with an Achilles tendon injury had suffered the same injury before.

Sein et al. (2010) found in swimmers that weekly mileage correlated significantly with tendonitis. Although there was no correlation between exposure hours during the year and tendon injury among our athletes, we found an association between fewer resting and recovery days per week in the training season and tendon injuries.

Joint injuries

High exposure time during the past year was associated with joint overuse injury among all athletes (gender- and sports-adjusted). A high amount of training may increase exposure to joint overuse injuries. A clear association was seen in the swimmers between the number of kilometres swum during the past year and an overuse joint injury. Nearly two-thirds of our swimmers' joint injuries were located in the shoulder region, as has also been reported in earlier studies (Richardson 1987, McMaster & Troup 1993, Johnson et al. 2003, Wolf et al. 2009).

Among our athletes, those with a higher BMI were more prone to report a joint injury. Messier et al. (2008) found no association between BMI and knee injury; however, injured athletes had higher body weight. This result may be due to loading being focused on the joints in running although it is a low-impact sport, and may explain why, in our study, in every second runner with at least one joint injury the injury occurred in the knee. Athletes with a joint injury reported fewer competitions during the year than those without a joint injury. This may be explained by longer absences from sports because of a joint injury. Taunton et al. (2002) reported that female athletes with a BMI of less than 21 are at increased risk for spine injuries. However, our athletes with a BMI lower than 21 had more overuse injuries in the lower extremities, and only a trend towards an association between higher BMI and low back overuse injury was found.

Ten percent of our skiers' overuse injuries were joint injuries, which is less than reported previously by Orava et al. (1985). This may be due the different diagnostic methods used in these studies. We used a self-report questionnaire whereas Orava et al. (1985) gathered their study group from an injury clinic along with a precise diagnosis.

Muscle injuries

Muscle injuries have been reported to be common among cross-country skiers (Sandelin et al. 1980, Orava et al. 1985, Smith et al. 1996), as also found in our study. Every third cross-country skier reported a muscle injury in the low back. Earlier studies (Eriksson et al. 1996, Bahr et al. 2004) have reported such injuries to be more common when using the classic rather than skating technique, as was also found in our study. The back is loaded by repetitive extension, deep flexion and rotation movements in classic skiing, while in skating skiing the spine is held in a more stable and upright position (Eriksson et al. 1996, Bahr et al. 2004). In contrast, Butcher and Brennen (1998), found no correlation between different skiing techniques and low back injury or all injuries.

Muscle injuries were also the most common type of injury in the shoulder region among swimmers. However, it may be that our self-report data does not differentiate reliably between injuries to tendon, joint or muscle.

Every fourth muscle injury was in the shin or calf, especially in the skiers and runners. Shin and calf injuries have also been found to be common among skiers (Smith et al. 1996) and runners (Rauh et al. 2000, Knobloch et al. 2008). However, we did not find any training-related risk factors for muscle overuse injuries.

6.4 Sports career termination due to injury

Based on our questionnaire study conducted at the end of the studied season, 27 athletes (5% of the athletes who responded to the question) reported that they had ended their sports career because of an injury. More female than male athletes reported terminating their sports career. Among the different sports groups, swimmers were the most prone to end their career, and in all cases the reason was a shoulder injury. Controversially, Sein et al. (2010) reported that none of their sample of swimmers permanently discontinued swimming because of their shoulder problem. Because the swimmers in our study group were young, another common contributory reason for ending their sports career was to embark on study programs. All the soccer players who terminated were females with severe knee injuries. The present author interviewed by telephone 20 of the 27 athletes who had reported ending their career, 7 to 11 months after the postal questionnaire. Five of these (25%) were continuing their sports career on the same level as earlier. Severe acute and overuse injuries to the large joints, shoulder and knee were the most common reasons for termination. Seventy percent of the athletes ending their career reported that injury caused them mild or moderate permanent disability in performing activities of daily life.

Kettunen et al. (2001) found that 20% of former male athletes from different sports reported that an injury was the main reason for ending their athletic career. However, their follow-up was 15 years, much longer than in our study, and this long follow-up explains the larger number of athletes terminating because of injury. In our study the interval between the postal questionnaire and interview was less than one year; this relatively short follow-up may explain the low number of terminating athletes. Drawer and Fuller (2001) found in their study of male former soccer players that nearly half of the responders had ended their sports career because of an injury, most commonly an overuse injury. Their study group consisted of male soccer players. Most of the injuries in their study that led to early retirement from sports were knee injuries. In our study the reasons for ending the sports career originated equally from acute and overuse injuries, although in all the soccer players the reason was an acute knee injury. Overall, our findings are in line with the earlier view that injuries play a significant role in the decision to terminate a sports career, and in some specific sports injuries may commonly be the main reason.

Although a high number of sports injuries occur in different sports each year, such injuries are not usually severe (Kujala et al. 2003b). Severe injury rates and patterns vary by sport, gender, and type of exposure (Darrow et al. 2009), and can also mean considerable loss of training and competition time (Hägglund et al. 2006). Our athletes who ended their career had significantly more injuries per 1000 exposure hours than those who continued with the sports. On average they lost over four months' training and competition time during the past twelve months. Long absence from a regular exercise program because of severe injuries may be frustrating for an athlete. Based on the reported exposure hours, the injured athletes had continued to train despite their injuries, but they had fewer competitions and training camp days than the athletes who continued with their sports. It might be worthwhile to focus more specifically on athletes who are physically active but spend long periods away from competitions and hard training and are at risk for ending their sports career, in order to reduce that risk. It is important to plan proper rehabilitation programs or overall training methods which would improve the healing process.

ACL injuries are usually severe and time loss because of such an injury can be long (Faude et al. 2005, Jacobson & Tegner 2007). Söderman et al. (2002) reported that within 2-7 years of an ACL injury most of their sample of young female soccer players (78%) had stopped playing soccer, most commonly because of symptoms in their injured knee. Among our career-ending athletes all the ACL injuries occurred to female soccer players. Two of them had an ACL injury in both knees and three out of five athletes had undergone a knee operation because of such an injury. However, it has been reported that it is possible to return to elite sports within a year following ACL reconstruction with appropriate rehabilitation (Waldén et al. 2011a). Most of our career-ending athletes with a knee injury had pain and disability in squatting, while jumping was also difficult for them. Despite their injuries and symptoms, most of the athletes continued at least to engage in regular leisure-time physical activity after ending their sports career. However, severe injuries with extended loss of time from training may negatively affect an athlete's motivation to rehabilitate himself/herself for a return to elite sports. This may be one of the reasons for the decision to stop his/her sports career. Ending their sports career is a matter of considerable importance for athletes and may possibly hamper their participation in leisure physical activity in later life (Kujala et al. 2003b). However, if we consider health from the viewpoint of an athlete's later years, it may be that in the case of some sports injuries the decision to end a sports career is preferable to rehabilitation. This is worth remembering, as e.g. sports-related increased risk for knee osteoarthritis has been explained by knee injuries (Kujala et al. 2003a, Thelin et al. 2006). Also in this connection it is important for the athlete to know what he/she can do to reduce the risk of injury. One of the most crucial issues is to find and deploy methods of preventing severe injuries that may terminate an athlete's career. The proper care and rehabilitation of injured athletes is therefore essential.

In all the sports groups in this study, the athletes who terminated their career were somewhat older than those who continued, and career-ending athletes had more acute and overuse injuries that those who continued their career. The different loading patterns characteristic of the different sports were also associated with the injuries sustained: swimmers had shoulder region injuries, soccer players' knee region injuries, and long-distance runners and cross-country skiers lower extremity injuries; the latter were mainly overuse injuries such as stress fractures. It seems that older athletes with sports-specific injuries are at increased risk for terminating their career.

The impact of an athletic injury is dependent on a number of factors such as the nature and severity of the injury and the importance of sports in the athlete's life. Fear of re-injury and fear of movement of the injured anatomical site are important psychological factors for athletes not returning to sports, especially after a severe injury (Kvist et al. 2005, Chmielewski et al. 2008, Silbernagel et al. 2011). Athletes who reported a career-ending injury expressed significantly lower levels of life satisfaction than their non-injured counterparts (Kleiber & Brock 1992). However, Perna et al. (1999) concluded that athletes with a severe athletic injury were no less satisfied with their lives than non-injured or moderately injured athletes. Many athletes have found that they are unable to return to their previous physical activity level (Nyland et al. 2002), and are therefore dissatisfied. In this study we did not investigate the effects of injury on self-esteem or life satisfaction. However, many athletes reported decreased motivation as one important reason alongside their injury. It may be that gender and other factors such as embarking on further education may influence the decision to terminate a career in sports.

6.5 Clinical implications and need for future research

Cross-country skiing is a safe sport with a low acute and overuse injury rate. However, excessive training (over 700 h/yr) predisposes to a two-fold higher risk, and less than two days weekly resting and recovery time predisposes to a five-fold higher risk, for overuse injuries in endurance athletes. Severe injuries such an overuse injuries in the foot, especially in the Achilles tendon and ACL injuries in the knee, cause extended loss from training and competition, especially in long-distance runners and soccer players. All swimmers ending their sports career suffered from a shoulder-region injury and soccer players from an ACL injury.

Training programs should be tailored individually for each athlete. It is also important to ensure a healthy relationship between vigorous training and resting and recovery time after training, and allow the tissues an appropriate length of recovery time. It is also necessary for athletes and their coaches to know and understand how to modify training after injury - such as what can be done and what should be taken into account. The proper care and rehabilitation of an athlete with an injury is essential to prevent the recurrence of injuries. However, if we consider health in the athlete's later years, it may be better to end a sports career after certain kinds of injuries than try to rehabilitate so as to continue in top-level sports. Notwithstanding, one of the most important things is to find out and use preventive methods to avoid severe and recurrent injuries, which may complicate the athlete's life and even lead to termination of the athlete's sports career.

In our study, no severe permanent disabilities occurred due to injury. However, minor and moderate disability was reported among career-ending athletes. Clearly, more prospective follow-up studies are needed to study injuries in sports the different loading patterns to obtain more specific information about injury etiology and mechanisms. In addition, intervention studies with different training programs are needed to clarify what kind of training would be effective in preventing injuries.

7 MAIN FINDINGS AND CONCLUSIONS

Based on this retrospective twelve-month study, we conclude that:

1. Top-level soccer players more commonly had acute injuries than cross-country skiers, swimmers or long-distance runners. In soccer, half of all acute injuries occurred during matches. Also, half of all acute injuries occurred in contact situations. In soccer and cross-country skiing, the most common acute injury was an ankle injury. Among runners, the most acute injuries were in the foot and among swimmers in the back.

2. Almost every second athlete had at least one overuse injury during the twelve-month follow-up. The highest prevalence of overuse injuries was found among long-distance runners. The most common location of an overuse injury correlated with the most loaded anatomical structure, such as shoulder injuries among swimmers, foot injuries among long-distance runners, and ankle injuries among soccer players and skiers.

3. In cross-country skiers, both acute and overuse injuries occurred mainly in an event other than their own. Among swimmers, acute injuries occurred mainly in non-swimming exercises, whereas their overuse injuries occurred were mainly swimming-related.

4. Male athletes more commonly had at least one acute injury than female athletes, especially among soccer players. Male long-distance runners also had a higher prevalence of at least one overuse injury than female runners. However, the other gender differences found were quite small: male athletes more commonly had posterior thigh overuse injuries and female athletes more commonly had ankle overuse injuries. Muscle injuries were more prevalent in male than female athletes, whereas ligament injuries were more common among female athletes.

5. Vigorous training during a year (over 700 hours/year) was a risk factor for an overuse injury among endurance athletes. Older athletes with less weekly resting and recovery time during the training season more commonly had at least one overuse injury. Older athletes also more commonly reported a tendon injury. Joint injuries occurred more often in the athletes, who's BMI was greater.

6. The older athletes with sports-specific injuries were at increased risk for terminating their career. Athletes who had terminated their sports career reported severe injuries, such as ACL injuries among female soccer players, with extended loss of time from training and competitions. All the swimmers who ended their career suffered from a shoulder injury. Most of the athletes who terminated their career because of injury had mild or moderate permanent disability. However, all the athletes who had ended their career were still physically active.

In conclusion, cross-country skiing is a safe sport with low injury risk, and can be recommended not only to top-level athletes but also to other physically active people. Vigorous athletic training without enough resting and recovery time may predispose an athlete to risk for an injury, especially an overuse injury.

8. YHTEENVETO

Tutkimuksen tarkoituksena oli kartoittaa eri tavalla kuormittavien urheilulajien vammaprofiilia suomalaisilla huippu-urheilijoilla kyselyä edeltäneen vuoden aikana. Kyselylomake lähetettiin vuonna 2006 kilpailukauden jälkeen hiihtäjille (n=300), uimareille (n=268), kestävyysjuoksijoille (n=265) ja jalkapalloilijoille (n=367). Tutkimusryhmä muodostui kauden 2005 lopussa ranking-listan kärjessä olleista 15-35 -vuotiaista mies- ja naisurheilijoista. Kyselyyn vastasi 149 hiihtäjää, 154 uimaria, 143 kestävyysjuoksijaa ja 128 jalkapalloilijaa. Vastausprosentti oli 53%. Kysymykset koskivat mm. urheilijoiden harjoitteluhistoriaa, äkillisten vammojen ja rasitusvammojen määrää, anatomista sijaintia, vammatyyppiä sekä vammoista aiheutuneita poissaoloja harjoittelusta ja kilpailuista. Tarkemmin tarkasteltiin sukupuolten välisiä vammaeroja ja kestävyysurheilijoiden rasitusvammojen riskitekijöitä.

Jalkapalloilijoista 73%:lla oli vähintään yksi äkillinen vamma kyselyä edeltäneen vuoden aikana ja puolet kaikista äkillisistä vammoista tuli ottelun aikana. Keskimäärin joka kolmannella kestävyysurheilijalla oli ollut vähintään yksi äkillinen vamma. Nilkkavammoja oli kaikista äkillisistä vammoista yleisimmin hiihtäjillä (25%) ja jalkapalloilijoilla (24%). Jalkapalloilijoilla seuraavaksi yleisimmät vammakohdat olivat polvi (21%) ja reisi (17%). Hiihtäjien toiseksi yleisin äkillinen vamma kohdistui selän alueelle (17%). Juoksijoiden kaikista äkillisistä vammoista 24% esiintyi jalkaterän alueella ja joka viidennellä vammautuneella juoksijalla oli polvivamma (22%). Uimareiden yleisimmät äkilliset vammat jakautuivat tasaisesti selän (18%), polven (17%) ja olkapään alueille (16%). Yleisimmin vammat olivat lihaskramppeja tai lihasrepeämiä sekä nivelsiteiden venähdyksiä. Kahdeksankymmentä prosenttia hiihtäjien ja 60% uimareiden äkillisistä vammoista sattui pääosin muissa lajeissa kuin urheilijoiden päälajissa.

Keskimäärin joka toisella urheilijalla esiintyi vähintään yksi rasitusvamma kyselyä edeltävän vuoden aikana. Rasitusvammoja oli eniten kestävyysjuoksijoilla (59%) ja vähiten jalkapalloilijoilla (42%). Juoksijoiden yleisimmät rasitusvammat esiintyivät jalkaterän alueella sisältäen akillesjännevammat (41%) ja polvessa (16%). Myös jalkapalloilijoilla (28%) ja hiihtäjillä (22%) yleisimmät rasitusvammat kohdistuivat jalkaterän alueelle. Suurin osa uimareiden rasitusvammoista syntyi uinnissa ja yli puolet uimareiden rasitusvammoista esiintyi olkapään alueella. Hiihtäjät eivät juuri lainkaan raportoineet olkapään seudun vammoja, vaikka myös hiihdossa kuormitetaan yläraajoja ja olkapään aluetta. Yleisimmät rasitusvammat urheilijoilla oli jänteissä ja lihaksissa.

Jalkapalloilijoiden äkilliset vammat aiheuttivat keskimäärin lähes kahden kuukauden poissaolon harjoittelusta ja otteluista. Juoksijoilla poissaolot olivat lyhyemmät kuin jalkapalloilijoilla, mutta silti keskimäärin 1,5 kuukautta. Rasitusvammojen takia juoksijat (53 pv/vuosi) olivat hieman enemmän poissa harjoittelusta ja kilpailuista kuin jalkapalloilijat (48 pv/vuosi). Vaikka hiihtäjillä ja uimareilla oli myös paljon rasitusvammoja, poissaolot harjoittelusta ja kilpailuista olivat vähäisempiä kuin juoksijoilla ja jalkapalloilijoilla. Tämä voi johtua juoksijoiden ja jalkapalloilijoiden vaikeammista vammoista mm. polvessa ja nilkassa. Lähes 40% kaikista vammoista oli uusiutuneita vammoja.

Vammojen esiintyvyydessä ei ollut suuria eroja sukupuolten välillä. Miehillä oli useammin vähintään yksi äkillinen vamma vuoden aikana kuin naisilla. Vähintään yhden rasitusvamman esiintyminen oli miesjuoksijoilla yleisempää kuin naisjuoksijoilla. Naisilla oli enemmän nivelsidevammoja kuin miehillä, kun taas miehillä oli enemmän äkillisiä lihasvammoja. Äkillisen nilkkavamman ilmaantuvuus 1000 harjoittelu- ja kilpailutuntia kohden oli naisilla kaksinkertainen miehiin verrattuna, vastaavasti miehillä oli lähes kuusinkertainen riski saada reiden takaosan rasitusvamma. Naisilla puolestaan oli kolminkertainen riski saada nilkan rasitusvamma miehiin verrattuna.

Rasitusvammoihin liittyviä riskitekijöitä kartoitettiin hiihtäjillä, uimareilla ja kestävyysjuoksijoilla. Vanhemmilla urheilijoilla oli suurempi riski saada rasitusvamma kuin nuoremmilla. Urheilijoilla oli yli viisinkertainen riski saada rasitusvamma, jos lepopäiviä harjoittelukauden aikana oli alle kaksi päivää viikossa. Kun tarkasteltiin harjoittelu- ja kilpailutunteja vuoden aikana, yli 700 tuntia vuodessa harjoitelleilla urheilijoilla oli kaksinkertainen riski saada rasitusvamma kuin alle 700 tuntia harjoitelleilla. Jännevammoja esiintyi yleisimmin urheilijoilla, jotka olivat vanhempia ja pitivät vähemmän viikoittaisia lepopäiviä harjoittelukauden aikana. Niveleen kohdistuvat rasitusvammat olivat yleisempiä urheilijoilla, joiden kehon painoindeksi oli suurempi kuin 21.

Tutkimusryhmästä 9% ilmoitti lopettaneensa urheilu-uransa kyselyä edeltäneen vuoden aikana ja heistä puolet vamman vuoksi. Yli 70% urheilu-uransa lopettaneista urheilijoista raportoi vamman haittaavan toimintakykyä. Keväällä 2007 haastateltiin puhelimitse urheilu-uransa vamman vuoksi lopettaneita urheilijoita. Kahdestakymmenestä urheilijasta 15 oli lopettanut huippu-urheilu-uransa, yksitoista kilpaurheilun kokonaan ja neljä oli siirtynyt alemmalle kilpailutasolle. Neljännes urheilijoista kuntoutui vammastaan ja he jatkoivat aiemmalla kilpailutasolla. Kaikki uransa lopettaneet jalkapalloilijat olivat naisia ja heistä jokaisella oli polven eturistisiderepeämä. Kaikilla urheilu-uran lopettaneilla uimareilla oli vamma olkapään alueella. Alentunut motivaatio huipputasolla urheiluun oli vamman lisäksi tärkein syy urheilu-uran lopettamiseen. Kaikki jatkoivat liikuntaharrastustaan, nyt vain pienemmällä teholla ja määrällä.

Johtopäätöksenä voidaan todeta, että maastohiihto on vähäisen vammariskin vuoksi turvallinen urheilulaji ja sitä voidaankin suositella huippu-urheilijoiden lisäksi myös kuntoilijoille. Hyvin kuormittava harjoittelu ilman riittävää lepoa voi altistaa erityisesti rasitusvammoille kestävyyslajeissa.

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APPENDICES I-III

University of Jyväskylä
Sports injury study
To be filled in by the researcher. Respondent's code:_________

SPORTS INJURY STUDY

The purpose of this questionnaire is to gather information about sports injuries, their incidence, how they have occurred and other related data. Read the questions carefully and circulate the alternatives that best apply to your own situation or write the answer in the space provided. If necessary, you can exceed the space allocated.

Do not leave items or questions unanswered, as this may prevent many other questions from being analyzed.

Your answers are just as important to this study whether or not you have sustained any sports injuries or whether or not you have already ended your sports career.

A1. BASIC DATA

1. Response date: ____/____/ 2006

2. Sex 1. Female
2. Male

3a. Age___________ **year** **3b. Date of birth** ____/____/ 19___

4. Height ______ cm

5. Weight _______ kg

6. Has your weight changed more than 3 kg during the past 12 months?
1. No
2. Yes
   1. My weight has increased by _______ kg
   2. My weight has decreased by _______ kg

7. Do you have any chronic diseases?
1. None
2. Allergy
3. Asthma
4. Diabetes
5. Epilepsy
6. Heart disease
7. Other, if so, please define____

8. Do you use regular medication?

1. None
2. Pills or other hormone preparation
3. Allergy medication
4. Asthma medication
5. Insulin
6. Epilepsy medication
7. Heart- or blood pressure medication
8. Other. If so, please describe____

9. What kind of diet do you follow?

1. Mixed diet
2. Vegetarian diet
3. Gluten-free diet
4. Lactose-free diet
5. Other. If so, please define ____

10. Which of the following alternatives best describe your smoking habits?

1. I smoke <u>at least</u> 20 cigarettes a day
2. I smoke 10 – 19 cigarettes a day
3. I smoke <u>at most</u> 9 cigarettes a day
4. I smoke once a week or often, not daily
5. I am abstaining from smoking or I have given up smoking
6. I have never smoked

11. Have you used snuff? How many times in all up to the present?

1. I use snuff regularly
2. I have used snuff over 50 times
3. I have used snuff 2 – 50 times
4. I have tried snuff snuff once
5. I have never tried snuff

12. How often do you consume alcoholic drinks? Include in your answer the occasions when you used a small amount of alcohol, e.g. half a bottle of beer or a small glass of wine.

1. Every day
2. A couple times a week
3. Once a week
4. A couple times a month
5. About once a month
6. About once every other month
7. 3 – 4 times a year
8. Once a year or less frequently
9. I do not consume alcohol at all

13. How strenuous is your work / study physically? If you are not working/studying, please circulate the first option.

1. I mainly sit at work and I do not walk much during my working day.
2. I walk quite a lot at work, but I don't have to lift or carry heavy items.
3. I have to walk and do a lot of lifting at work or use stairs or walk uphill.
4. My job is manual work, where I have to lift or carry heavy things, do digging, shoveling etc.

Menstruation (female respondents)

14. Has your menstruation begun?

1. No
2. Yes. If so, at what age? ________
    a. My menstruation is regular, the cycle is about_____ days
    b. My menstruation is irregular, about _____times per year, the longest period lasts about _____ days, the shortest period about _____ days
    c. My menstruation began, but then it stopped ____ / ____ (month / year)

A2. SPORTS EVENTS AND TRAINING HISTORY DATA

This section is about the sports training and competition you have participated during the past twelve months. Even if you find some questions difficult to answer with precision, for example the amount of training you have done, please don´t leave those questions unanswered, please give the best answer you can. If you have terminated your sports career, moved to a lower level or changed your sports event, please answer the questions according to your training program in the beginning of the season prior to this change.

15a. Sports event: ____

15b. If you are involved in team sports, what is your main playing position?

1. Goalkeeper
2. Defender
3. Striker
4. Other. If so, what? ____

16. At what age did you start training for your main sports? ______ years of age

17. How many years have you been in active training for your main sports (at least 2 times / week)? _______ years

18. Do you train for other sports? By 'other sports' is meant a sport(s), which is not included in your training program for your main sports.

1. No
2. Yes. If so, what sports event (s)? ____

19. Do you compete or participate in matches in other sports events than your main sports event(s)?

1. No
2. Yes. If so, in what sports events?____

20. How long is your annual mean training season (the part of the year when you do training regularly but don't compete regularly in your main sports)?
______ months

21. If you include all your sports how much do you spend on average for weekly training <u>during the training season?</u>

______ hours / week, ______ times / week

22. How long is your annual mean competition season? Add together all the different competition seasons, if more than one season exists.

______ months

23. If you include all your sports, how much on average do you spend for weekly training <u>during the competition season?</u>

______ hours / week, ______ times / week

24. How many competitions / matches have you participated on average during the past twelve months?

______ competitions or matches / year

25. On average, how long did a competition / match last?
1. competition / match _______ minutes
2. competition / match (with warming up and cooling down) _______ minutes

26. How many training camp days have you had in total during the past twelve months?
_______ days

27. How many whole resting days <u>per week</u> do you have on average <u>in the training season?</u>
_______ resting days / week

28. How many resting days <u>per week</u> do you have on average <u>in the competition season</u>?
_______ resting days / week

***) There are a couple of questions, which are focused on the specific sports events (Appendix II).*

Looking after the musculoskeletal system

The next section concerns maintenance of the fitness of the musculoskeletal system. This includes activities such as warming up, cooling down, stretching, massage and other self-initiated training outside of training for your main sports.

29. Do you warm up <u>before</u> a training session or competition?
1. No
2. Occasionally
3. Yes

30. Do you cool down after a training session or competition?
1. No
2. Occasionally
3. Yes

31. How often on your own initiative do you do stretching?
1. Never
2. Less than 1 time / week
3. 1 – 3 times / week
4. Every day or almost every day

32. How often do you take a massage?
1. Never
2. Less than once a month. If so, how often?_________________________________
3. Once a month
4. Every second week
5. Once a week or more

33a. Do you, besides sports training, do additional training on your own, for example resistance training with a rubber band or proprioceptive/balance training? If you do not do additional training by yourself, please go to part B, question 34 on acute injuries.
1. No
2. Yes

33b. If you responded yes to 33a, what kind of additional training do you do and how often?

	No	Yes	Times/Week
1. Toe or foot exercises			
2. Ankle exercises			
3. Muscular fitness or trunk muscle exercises			
4. Exercises of deep muscles in trunk or Pilates			
5. Joint-stabilizing or other stabilizing exercises			
6. Flexibility exercises			
7. Recovering jogging, aqua running or swimming			
8. Other exercises. If so, please define?			

B. SPORTS INJURIES

This section includes three parts. Please follow the instructions, even if you have already terminated your sports career.

B1. ACUTE INJURIES

This part focused on acute injuries. Please, read the following paragraph carefully before proceeding further.

An acute sports injury occurs suddenly or accidentally, interrupting the training or the competition of the athlete or causing an identifiable trauma. An acute injury is any

physical injury that keeps the athlete away from <u>at least one training session, or competition</u>, or needs a physician's care. Overuse injuries are described in part C.

34. Have you had an acute sports injury <u>during the past 12 months</u>?

1. No
2. Yes. If so, how many acute injuries have you had? ______________

If you have not had any acute sports injury, please proceed to part CI, question 49.

Please tick the box that best describes the site of the acute injury or injuries (maximum 5 injuries) that you have sustained during the past twelve months. Select the alternative that most closely corresponds to each injury. The numbering concerning all acute injuries is similar. If you have had more than 5 injuries during the past 12 months, list what you consider to be the most <u>severe five injuries in order of severity</u>.

The most severe acute injury (Injury 1) is the injury which has caused you <u>the longest absence</u> from training and/or competition, or permanent disability, or has even terminated your sports career in its present form. The next severe injury will be marked as Injury 2, and so on.

35. Where was the acute injury located?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Toes					
2. Metatarsus					
3. Sole					
4. Heel					
5. Achilles tendon					
6. Ankle					
7. Calf					
8. Lower leg					
9. Knee					
10. Thigh					
11. Hamstring					
12. Hip					
13. Buttock					
14. Pelvis					
15. Groin					
16. Abdomen					
17. Low back					

18. Thorax					
19. Upper back					
20. Neck					
21. Face					
22. Teeth					
23. Eyebrow					
24. Other head injury					
25. Clavicle					
26. Between neck and shoulder					
27. Shoulder					
28. Upper arm					
29. Elbow					
30. Forearm					
31. Wrist					
32. Palm					
33. Thumb					
34. Other finger					

36. What kind of acute injury was it? From the list of injury types, tick the box that best describes each injury (Injury 1, Injury 2, etc).

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Muscle cramp					
2. Muscle rupture/sprain					
3. Contusion					
4. Wound					
5. Strain of ligament					
6. Rupture of ligament					
7. Luxation/dislocation of joint					
8. Fracture					
9. Unidentified pain					

37. What was the diagnosis of the acute injury and when did the injury occur? If you don´t remember the precise diagnosis, please describe the injury in your own words.

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1) Diagnosis of the acute sports injury or description in your own words					
2) The day the acute injury occurred (month/year)					

38. In what situation did the acute injury occur?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Tackling					
2. Being kicked by other players					
3. Crashing					
4. Falling					
5. Slipping					
6. Side-stepping, turning					
7. Running					
8. Decelerating					
9. At push-off					
10. Landing					
11. Passing/throwing					
12. Shooting at goal					
13. Falling down					
14. Technical error					
15. Transferring weight					
16. Striking with hockey stick, racquet, bat etc.					
17. Defensive action					
18. Trying to reach, ball, puck etc.					
19. Stretching					

***) There are a couple of questions which are focused on the specific sports events (Appendix II).*

39. When did the acute injury occur?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. During training by yourself					
2. During supervised individual exercise					
3. During team training					
4. During a competition / match					
5. During warming up before or cooling down after performance					

***) There are a couple of questions which are focused on the specific sports events (Appendix II).*

40. How long were you absent from training or competing because of the acute injury? For each injury select either <u>training season (Ts) or competition season (Cs)</u>

	Injury 1		Injury 2		Injury 3		Injury 4		Injury 5	
	Ts	Cs	Ts	Cs	Ts	Cs	Ts	Cs	Ts	Cs
1. No absence										
2. 1 – 3 days										
3. 4 – 6 days										
4. 1 – 3 weeks										
5. Over 3 weeks and less than 3 months										
6. Over 3 months and less than 6 months										
7. Over 6 months										

41. Please give an estimate of how long in total you have been absent from training or competition because of acute injuries during the past 12 months?

_______________ months
_______________ weeks
_______________ days

42a. How was the acute injury treated? Note: You can choose one or more alternatives. First aid means having a cold compress, elevation or compression of the affected area administered by yourself or by somebody else. (coach, supporter, team-mate, doctor)

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Nothing					
2. First aid					
3. Instructions about rest or rehabilitation					
4. Brace / taping or other aid					
5. Medication					
6. Massage					
7. Physiotherapy					
8. Stitches / wound care					
9. Surgery					

42b. If you had to use a brace or aid, please state what it was and for what injury it was used?

____

____

43. Have you been involved in any accidents during the past twelve months during travel to the sports location (during the journey, not during the actual training/ performance) which have caused at least one week's absence from training or competing?

1. No
2. Yes. If so, then

   a. how many? ________

   b. how long were you absent from training and competing?

   _________months________days

Please, describe more specifically, what kind of injury/trauma you sustained.

____

____

44. Have you injured yourself in any other way during the past 12 months (during leisure time, at work, etc.)?

1. No
2. Yes

   If yes, please define where and how?

____

B2. RECURRENCE OF ACUTE SPORTS INJURIES

The following questions concern the recurrence of acute sports injuries.

45. Have you previously sustained the <u>same acute injury in the same anatomical site</u> during your sports career?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. No					
2. Yes.					
When? (month/year)					

46a. Have you sustained <u>any other acute injury in the same anatomical site</u> before?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. No					
2. Yes.					
When? (month/year)					

If you have not had any recurrent acute sports injuries, please proceed part C1, question 49.

46b. If you responded yes to the previous question, what kind of recurrent acute injury was it?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Muscle cramp					
2. Muscle strain/rupture					
3. Contusion					
4. Wound					
5. Strain of ligament					
6. Rupture of ligament					
7. Luxation/dislocation of joint					
8. Fracture					

47. Did you get any instructions from a doctor/ physiotherapist about rehabilitation of the <u>injury</u> on the first occasion before it recurred?

	Injury 1		Injury 2		Injury 3		Injury 4		Injury 5	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
1. Self-treatment (for example taping, cold compress)?										
2. Modified training?										
3. Information about starting training for own sports?										
4. Information about starting competition?										

If you didn't receive any instructions on rehabilitation of the injury, please proceed to part C1, question 49.

48. Did you follow the instructions that you were given after the first acute injury?

	Injury 1		Injury 2		Injury 3		Injury 4		Injury 5	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
1. Self-treatment (for example taping, cold compress)?										
2. Modified training?										
3. Information about starting training for own sports?										
4. Information about starting competition?										

C1. OVERUSE INJURIES

This section focused on overuse injuries. Please read the following paragraph carefully before answering.

An injury causes pain during exercise loading <u>without any noticeable external cause of injury.</u> The injury gradually causes worsening of pain during or after exercise. Pain becomes worse when loading is continued and may stop exercise completely.

49. Have you had an overuse injury <u>during the past 12 months</u>?

1. No
2. Yes. If so, how many different overuse injuries? ___________

If you have not had any overuse injuries, please proceed to question 63.

Please tick here for maximum of five overuse injuries sustained during the past 12 months the option that most closely corresponds to each of the injuries. The numbering concerning all overuse injuries are similar. The most serious overuse injury (Injury 1) can be considered as the injury, which causes <u>the longest absence</u> from training and / or

competition, or some degree of permanent injury or even for today's sports career termination. The next severest injury is Injury 2 etc.

50. Where was the overuse injury located?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Toes					
2. Metatarsus					
3. Sole					
4. Heel					
5. Achilles tendon					
6. Ankle					
7. Calf					
8. Lower leg					
9. Knee					
10. Thigh					
11. Hamstring					
12. Hip					
13. Buttock					
14. Pelvis					
15. Abdominal					
16. Low back					
17. Thorax					
18. Upper back					
19. Neck					
20. Between neck and shoulder					
21. Shoulder					
22. Upper arm					
23. Elbow					
24. Forearm					
25. Wrist					
26. Palm					
27. Thumb					
28. Other finger					

51. In what tissue did the overuse injury occur?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Muscle					
2. Tendon					
3. Bone					
4. Joint					
5. Ligament					
6. Nerve tissue					

52. What kind of overuse injury was it?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Stress fracture					
2. Tendonitis					
3. Bursitis					
4. Nerve impingement					
5. Other, If so, please define					

***) There are a couple of questions which are focused on the specific sports events (Appendix II).*

53. What was the diagnosis of the overuse injury and when did it occur? If you don´t remember the precise diagnosis, please describe the injury in your own words.

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1) Diagnosis of the overuse sports injury or description in your own words					
2) The day the overuse injury occurred (month/year)					

54. How long were you absent from training or competing because of the overuse injury? For each injury select either training season (Ts) or competition season (Cs)

	Injury 1		Injury 2		Injury 3		Injury 4		Injury 5	
	Ts	Cs	Ts	Cs	Ts	Cs	Ts	Cs	Ts	Cs
1. No absence										
2. 1 – 3 days										
3. 4 – 6 days										
4. 1 – 3 weeks										
5. Over 3 weeks and less than 3 months										
6. Over 3 months and less than 6 months										
7. Over 6 months										

55. Please give an estimate of how long in total you have been absent from training or competition because of overuse injuries during the past 12 months?

_______________ months
_______________ weeks
_______________ days

56a. How was the overuse injury treated? Note: You can choose one or more alternatives. First aid means having a cold compress, elevation or compression of the affected area administered by yourself or by somebody else. (coach, supporter, team-mate, doctor ….).

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Nothing					
2. First aid					
3. Instructions about rest or rehabilitation					
4. Brace / taping or other aid					
5. Medication					
6. Massage					
7. Physiotherapy					
8. Stitches / wound care					
9. Surgery					

56b. If you had to use a brace or aid, please state what it was and for what injury it was used?

____

____

57. Do you think external factors (for example surface, venue or weather) were connected with the overuse injury?

1. No
2. Yes. If so, please define the factors? ____

____

58. Do you think footwear contributed to the overuse injury?

1. No
2. Yes. If so, please define the footwear?__________________________________

____

C2. RECURRENCE OF THE OVERUSE INJURY

59. Have you previously sustained the <u>same overuse injury in the same anatomical site</u> during your sports career?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. No					
2. Yes. If so when? (month/year)					

60a. Have you had <u>any other overuse injury in the same anatomical site</u> before?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. No					
2. Yes. If so, when? (month/year)					

If you haven't had any recurrent overuse injuries, please proceed to question 63.

60b. If you answered yes to the earlier questions, in which tissue did the recurrent overuse injury occur?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Muscle					
2. Tendon					
3. Bone					
4. Joint					
5. Ligament					
6. Nerve tissue					

61. Did you get any instructions from a doctor/ physiotherapist about rehabilitation of the <u>overuse injury</u> on the first occasion before it recurred?

	Injury 1		Injury 2		Injury 3		Injury 4		Injury 5	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
1. Self-treatment) (for example taping, cold compress)?										
2. Modified training?										
3. Information about starting training for own sports ?										
4. Information about starting competition?										

If you did not receive any instructions about rehabilitation of the injury, please proceed to question 63.

62. Did you follow the instructions you received about rehabilitation of the first overuse injury?

	Injury 1		Injury 2		Injury 3		Injury 4		Injury 5	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
1. Self-treatment) (for example taping, cold compress)?										
2. Modified training?										
3. Information about starting training for own sports?										
4. Information about starting competition?										

63. How long in total do you estimate you have had to be absent from training or/and competition because of acute and overuse injuries combined during the past 12 months?

_______________ months
_______________ weeks
_______________ days

D. SPORTS INJURIES AND TERMINATION OF SPORTS CAREER

This section focused on the contribution of sports injuries to the termination ending of your sports career. Please read the following paragraph carefully before answering.

In this study terminating a sports career means no longer continuing the career on the level at which you have been training and actively competing. A sports career is also considered terminated where the athlete has continued to participate in the same sports but at a lower level (less targeted), or whether the athlete had changed his or her event.

64. Have you terminated your sports career according to the definition given above?
1. No
2. Yes

If you have not ended your sports career, please proceed to question 68.

65. Did your sports injury influence your decision to end your sports career?
1. No, it did not
2. It had an influence on my decision
3. I ended my sports career because of the sports injury

If a sports injury did not influence your decision to end your sports career, please proceed to question 68.

66. When, according to the definition of termination given above, did you end your sports career? _____________ (month/year)

67. Which sports injury or injuries influenced to your decision to end your sports career?
____

68. How has your sports injury influenced your sports career? Please, circulate only one option.

1. **Transient mild disability**: The disability in itself did not compel you to quit the sport, but it contributed to your decision to terminate. You still had the choice of continuing in sport as before. You are able to continue in sports at a lower level or in different sports.

2. **Transient severe trauma:** You no longer compete at the same level as prior to your injury, but you are able to continue in sport at a lower level or in different sports. The trauma no longer causes symptoms.

3. **Mild permanent disability:** You no longer compete at the same level as prior to your injury, but you are able to continue in sport at a lower level or in a different event. Use of the injured area may cause symptoms, but the symptoms do not interfere with your everyday life.

4. **Moderate permanent disability**: You are unable to continue the sports. You are able to perform light and normal physical activities of daily living, but use on the injured site causes symptoms which disrupt your daily life.

5. **Serious permanent injury**: The injury impairs your physical function, so that coping with normal daily activities is clearly more difficult. The injury affects also your choice of occupation.

If you choose alternative 1 or 2, please proceed to page 21.

69. What symptoms has your injury caused in normal life outside sports?

Symptom	No	Yes
1. Pain at rest		
2.Pain when moving		
3. Radiating pain		
4. Stiffness		
5.Joint-restricted movement		
6. Joint – giving way symptom		
7. Swelling		
8. Other symptoms. If so, please define		

70. What daily movements or activities are difficult or cause problems because of your injury?

	No	Yes
1. Walking		
2. Running a short distance (i.e. to the bus)		
3. Jumping (i.e. over a ditch)		
4. Walking up stairs		
5. Walking down stairs		
6. Sitting		
7. Sitting down		
8. Getting up		
9. Lying supine		
10. Turning in bed		
11.Getting up from supine to sitting		
12. Squatting		
13. Standing		
14. Reaching up with the arms		
15. Reaching out with the arms		
16. Reaching down		

17. Rotating the trunk		
18. Standing on tiptoe		
19. Step up		
20. Supporting the injured limb		
21. Other. If so, please define?		

THANK YOU FOR YOUR ANSWERS!

Please fill in the informed consent overleaf, which will be detached from your questionnaire and stored separately.

SPORTS INJURY STUDY
INFORMED CONSENT FORM

I have read the information about the ***Sports injury study*** and I am aware of the purpose and the content of the study

☐ **I give my consent** to participate this questionnaire study, the purpose of which is to clarify the occurrence of sports injuries, and consent to the use of information I have given in my questionnaire for the above-described research purpose. I have the right to cancel my permission and cease to participate without my so doing having any influence on my future care or treatment.

☐ **I do not give my consent** to participation in the above-mentioned study and my information will not be used in the study.

Date: …………………………………………..… / 2006

Signature:………………………………………………………………………………

Printed name:…………………………………………………………………………….

Identification code:……………………………………………………………………...

Address:……………………………………………………………………………......

Telephone number: ………………………………………………………………………..

(Please give your telephone number so that you can be contacted if there is a need to clarify any information you have given)

Consent form received by: ……………………………………………………………

Printed name: ……………………………………………………………………………….

Date consent form received: ……………………………………………………………

QUESTIONS FOCUSING ON THE DIFFERENT SPORTS

CROSS-COUNTRY SKIING (CCS)

CCS 1. How many kilometres of skiing did you plan to do during the past 12 months?
a) Using the classic technique (competition and training season combined) _____ km
b) Using the skating technique (competition and training season combined) ____ km

CCS 2. How many kilometres of skiing did you actually do during the past 12 months?
a) Using the classic technique (competition and training season combined) ______km
b) Using the skating technique (competition and training season combined)_____ km

CCS 3. If you compare the number of kilometers you have skied (competition and training km combined) during the past year with the number skied during the preceding year, has it increased or decreased, and if so, by how much?
a) Increase of _________ km
b) Decrease of _________ km
c) Unchanged

CCS 4. In what kind of skiing situation was the acute injury sustained?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Downhill or just before					
2. On the flat					
3. On a slope					
4. During some other exercise / other sports event than cross-country skiing					

CCS 5. What sports activity caused the acute injury?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Skating technique					
2. Classic technique					
3.Skiing on roller skis					
4. Roller skating					
5. Some other exercise/ other sports event than cross-country skiing					

CCS 6. What sports activity caused the overuse injury?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Skating technique					
2. Classic technique					
3.Skiing on roller skis					
4. Roller skating					
5. Some other exercise/ other sports event than cross-country skiing					

SWIMMING (S)

S 1a. In what two swimming disciplines do you usually compete? Put your best swimming discipline first.

1.____________
2.____________

S 1b. Which of the following distances best describes your competition distance?

1. Short distances 50/100m
2. Medium length distances 200/400m
3. Distances over 400m

S 2. How many kilometres on average do you swim weekly during a training season?
______ km per week

S 3. How many kilometres on average do you swim weekly during a competition season?
______ km per week

S 4. Estimate how many kilometers you swim during the training season in each of the disciplines listed below, including kicks, hand pull and technique training.

1. Freestyle ________%
2. Butterfly ________%
3. Backstroke ________%
4. Breaststroke ________%

S 5. Estimate how many kilometers you swim during the competition season in each of the events listed below, including kicks, hand pull and technique training.

1. Freestyle ________%
2. Butterfly ________%
3. Backstroke ________%
4. Breaststroke ________%

S 6. If you compare the number of kilometers you have swum (competition and training swimming km combined) during the past 12 months with the number swum during the preceding year, has it increased or decreased, and if so, by how much?

1. Increased by _________ km
2. Decreased by _________ km
3. Unchanged

S 7a. Do you do weight training?
1. No
2. Yes

S 7b. If yes, at what age did you start weight training?

_____ years of age

S 7c. How often do you engage in gym exercises in the training season?

______ hours ______ times / week

S 7d. How often do you engage in gym exercises in the competition season?

______ hours ______ times / week

S 8. In what kind of swimming situation did you sustain the acute sports injury?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Contact with the lane ropes /pool wall					
2. Contact with another swimmer					
3. Baseline/ starting					
4. Turning					
5. Using "flippers"					
6. Kicking					
7. In a swimming pool using other resistance devices					

S 9. What training type caused the acute sports injury?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Butterfly					
2. Breaststroke					
3. Freestyle					
4. Backstroke					
5. Any other non-swimming training					

S 10. What training type caused the overuse injury?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Butterfly					
2. Breaststroke					
3. Freestyle					
4. Backstroke					
5. Any other non-swimming training					

LONG-DISTANCE RUNNING (LDR)

LDR 1. What is the longest average daily training distance in kilometers you run?
___________________ km

LDR 2. What kind of surface do you run on the most?
1. Asphalt
2. Dirt road
3. Soft jogging track, etc.

LDR 3. How many kilometres of running did you plan to do during the past 12 months?
____________________ km

LDR 4. How many kilometres of running did you actually do during the past 12 months?
____________________ km

LDR 5. If you compare the number of kilometers you have run (competition and training running km combined) during the past 12 months with the number run during the preceding year, has it increased or decreased, and if so, by how much?

1. Increased by _________ km
2. Decreased by _________ km
3. Unchanged

SOCCER (SO)

SO 1. Team in season 2006

____

SO 2. How many soccer games did you attend during the 2006 season?

a) National team__________________
b) Finnish Football League /Female Finnish League_____________
c) Finnish cup ___________________
d) Other __________________

SO 3. If the sports injury occurred in a match, was this national championship, Finnish Football League / Female Finnish Leaque, Finnish Cup or other match?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. International competition/national team					
2. Finnish Football League /Female Finnish Leaque					
3. Finnish Cup					
4. Other					

SO 4. If the sports injury occurred in the match, did it occur in the first or second half?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. First half					
2. Second half					

SO 5. On what kind of training/playing surface did the acute sports injury occur?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Grass (natural grass/football turf)					
2. Artificial turf					
3. Sand					
4. Crushed gravel					
5. Parquet floor/ plastic mat					
6. Other					

SO 6. Was the acute injury sustained in a situation involving another player?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. No					
2. Yes					

SO 7. Did your acute injury occur training/playing in the open air or indoors?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. In the open air					
2. In an indoor environment/sports hall					

SO 8. If the acute injury occurred in the open air, what kind of surface were you on (you can choose more than one option)?

	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
1. Dry					
2. Wet					
3. Uneven					
4. Flat					

SEMI-STRUCTURED QUESTIONNAIRE FOR ATHLETES TERMINATING THEIR SPORTS CAREER (SPRING 2007)
(Telephone interview)

The interview is based on the results of the sports injury questionnaire which was sent in 2006.

Basic data:

ID:__________

1. Sex
1. Female
2. Male

2. Age ________years.

Competitive sports:

3. Have you ended your sports career?
1. No
2. Yes

4. When did you end your sports career?
_____________________________ (Date, month / year)

5. On what level were you competing before termination?
____

6. If you have not ended your sports career, on what level are you currently competing in your sports?
____

7. Do you compete in any other sports?
1. No
2. Yes. Where? _______________________________________

8. Do you intend to return to competitive sports in your own sports?
1. No
2. Yes

9. What about in other sports?
1. No
2. Yes, which sports_______________________________________

10a. What kind of a sports injury led you to terminate your sports career?
- Anatomical site of the body? ______________________________
- Injury type?______________________________
- Acute injury? ______________________________
- Overuse injury?______________________________
- Diagnosis of the injury?______________________________

10b. What kind of treatment did you get for your injury?
1. Instructions on self-care
2. Massage
3. Physiotherapy
4. Medication (pain medication? injections?)
5 Surgery
6. Other hospital care
7. Rest

10c. Did you have to keep a long break from your sports after your injury?

____

10d. Did your injury contribute to your decision to end your competitive sports career?
1. No 2. Yes

10e. Was the injury / ailment the main reason for ending your competitive sports career?
1. No 2. Yes

11. Were there any other special reasons for stopping your sports career (military service pregnancy, studies, etc.)?
1. No
2. Yes. What? ______________________________

12. How did your injury affect your sports career (pain. etc)?

____

<u>Work</u>

13.Evaluate on a scale of 0-10 how much inconvenience your sports injury-related disability causes you at the moment?

13a. At work
0 ..... 1 ...... 2 ...... 3 ...... 4 ...... 5 ...... 6. ..... 7 ...... 8 ...... 9 ...... 10 Worst possible effect/
No effect at all Prevents me from working

13b. What kind of work does your injury prevent you from doing?

____

13c. How has your injury affected your ability to work?

____

14. What is your principal activity
1. Full-time work
2. Part-time work
3. Student
4. Retired
5. Unemployed or laid off
6. Taking care of own household or family members
7. Military or civilian service
8. Other? What?

____

15. How many full days have you been absent from work because of *a sports-related injury* in the past 12 months?

____________________ days

16. Have you had to change your career or job because of an injury?
1. No, I have not
2. Yes

17. How stressful is your job at the moment?
1. My work involves little or no physical exertion, since it is mainly sitting or standing and does not include handling heavy objects
2. My work involves mainly light physical activity and / or other light muscular effort /exertion
3. My job involves plenty of swift movement or other medium-heavy muscular effort /exertion
4. My job involves plenty of fast movement or other strenuous muscular effort /exertion

18. How do you cope with your *injury/disability* at work?
1. It does not affect my work at all
2. I am able to cope with at work, but it causes symptoms
3. Sometimes I need to lighten my work or to modify my way of working because of the injury
4. I often have to reduce the pace of my work or change my way of working because of the injury
5. I believe that because of the injury a part-time work would be best for me
6. I think I am unable to work because of the injury

<u>Other disadvantages caused by the injury</u>

19. Disabling effects on in leisure-time activities (caused by sports injury / ailment/disability) at the moment

0 ..... 1 ...... 2 ...... 3 ...... 4 ...... 5 ...... 6. ..... 7 ...... 8 ...... 9 10
No effects at all Worst possible effect
Where____

20. Disabling effects on performance of household tasks (i.e. caused by sports injury / ailment/disability) at the moment

0 ..... 1 ...... 2 ...... 3 ...... 4 ...... 5 ...... 6. ..... 7 ...... 8 ...... 9 10
No effects at all Worst possible effect

Where____

21. Has your injury been defined as belonging to a specific medical disability category?
1. No
2. Yes

What____

22. Are you currently in medical care because of an injury/an ailment?
1. No
2. Yes

23. How many times have you visited a doctor because of the sports injury (which caused career termination) in the past 12-month period? ______ times

24. Evaluate on a scale of 0-10 how much pain have you experienced because of the injury during the past seven days (7 days).

0 ... ... 1 ... ... 2 ... ... 3 ... ... 4 … ... 5 ... ... 6 ... … 7 … ... 8 ... ... 9 10
No pain at all Worst possible pain

25. Other possible diseases?

____

26. Have you used painkillers because of your injury during the past 12 months?
1 No
2 Yes

27. If you answered yes, how often?
1. Once a month or less
2. Twice a month
3. 1-2 days a week
4. 3-5 days a week
5. Every day or almost every day

Exercise/training

28. Do you still exercise or engage in sports during your free time?
1. No
2. Yes

29. On what sports?

Type Number of times a week

__________________ ________________________
__________________ ________________________
__________________ ________________________
__________________ ________________________

30. How would you describe the intensity of your leisure-time physical activity?

1. Walking pace
2. Between walking and easy running
3. Easy running (jogging)
4. Brisk running

31. How long on average do you spend on a leisure-time physical activity?

1. Less than 15 minutes
2. 15 – 30 minutes
3. 30 to 60 minutes
4. 1 - 2 hours
5. Over 2 hours

32. How many times a month do you engage in leisure-time physical activity?

1. Less than once a month
2. 1-2 times a month
3. 3-5 times a month
4. 6-10 times a month
5. 11-19 times a month
6. 20 times or more per month

Thank you for your time!

ORIGINAL PUBLICATIONS I - IV

I

I

Type of sport is related to injury profile: A study on cross country skiers, swimmers, long-distance runners and soccer players. A retrospective 12-month study

by

Leena Ristolainen, Ari Heinonen, Hanna Turunen, Heidi Mannström, Benjamin Waller, Jyrki A. Kettunen, and Urho M. Kujala

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MEDICINE & SCIENCE
IN SPORTS

Type of sport is related to injury profile: A study on cross country skiers, swimmers, long-distance runners and soccer players. A retrospective 12-month study

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This 12-month retrospective questionnaire compared the occurrence of sports injuries in 149 cross country skiers, 154 swimmers, 143 long-distance runners and 128 soccer players aged 15–35 years. Soccer had significantly more injuries (5.1 injuries/1000 exposure hour) than other sports (2.1–2.8, $P<0.001$). More runners than soccer players reported overuse injuries (59% vs 42%, $P=0.005$), locating typically in the foot in runners, soccer players and skiers. Swimmers reported overuse injuries in the shoulder more commonly than skiers (40% vs 1%, $P<0.001$), who also intensively load shoulders. Acute injuries in skiers (80%) and in swimmers (58%), and overuse injuries in skiers (61%), occurred during exercise other than own event. In soccer and running the absence time from sport because of injuries was significantly longer than in skiing and swimming. No severe permanent disabilities occurred due to injury but seven women quit sports because of injury. In conclusion, type of loading is strictly associated with the anatomical location of an overuse injury as shown by the difference in shoulder injury incidence between swimmers and cross country skiers. In some sports, a significant proportion of acute injuries occur in other than the main event.

Numerous injuries caused by sport occur each year, resulting in breaks from activity, disability and considerable medical costs (Requa et al., 1993; Center for Disease Control and Prevention, 2002; Conn et al., 2003). Although a high number of sport injuries occur in different sports, they are not usually severe (Kujala et al., 2003). Even then, injuries can cause time loss from training and competition (Hägglund et al., 2006), and subjects with a history of previous injury are at an increased risk for new injury (Van Mechelen et al., 1996; Murphy et al., 2003; Hägglund et al., 2006). Increased understanding of the mechanisms by which injuries occur would be of value both in the prevention of injuries and in tailoring substitute exercises or rehabilitation programs to meet the needs of injured individuals.

Different loading patterns may cause dissimilar injury profiles. Cross country skiing consists of repetitive pliant movements without impacts. Because of its almost complete lack of ground-impact, combined with a great number of movements, swimming is considered to be a repetitive, non-impact loading sport (Nikander et al., 2005). In long-distance running, the structures of the lower extremities are exposed to a large number of repetitive impacts (van Mechelen, 1992; Hreljac, 2004). Soccer is a typical impact sport, including rapidly accelerating and decelerating movements (Nikander et al., 2005). Soccer is also a team sport involving physical contact with other players.

Because athletes have several injuries, it is necessary to know the injury profile in a specific sport and how injuries can be prevented. The occurrence of injuries has been compared, using the same methodology, in only a few, sporadic studies (Bahr et al., 2004). Moreover, most of the studies investigating sport-related injuries have not studied acute and overuse injuries separately. Therefore, the aim of this study was to compare the occurrence of acute and overuse injuries, the role of previous injuries, time loss from training and competition and in addition, the reasons for stopping a career in athletes in different sports with differing loading patterns.

Material and methods

Subjects

We recruited 1200 competitive Finnish top-level male and female athletes (range 15–35 years) to this retrospective injury study, representing four different sports and loading modal-

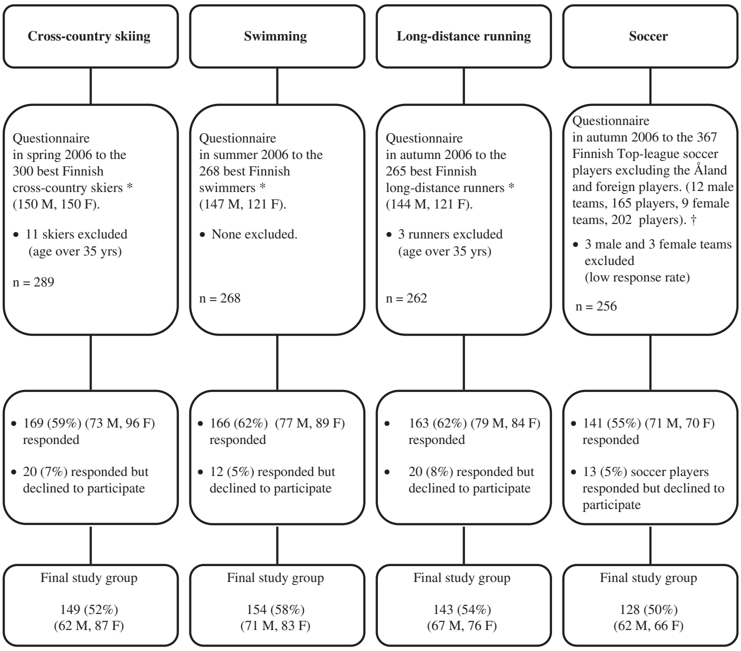

Fig. 1. Basic information from the study design. *Cross country skiing*: The best Finnish male and female skiers according to the ranking list of the Finnish Ski Association. *Swimming*: The best swimmers according to the FINA points system in 2005 over different swimming distances a 50 m pool were taken from the website of the Finnish Swimming Association. *Long-distance running*: All the female and male runners whose personal record in 2005 was better than the C level in one of the running distances from 1500 m to marathon were included in to the study. *Soccer*: Male and female players who played in the Finnish Top-league were chosen from the list posted on the Football Association of Finland website. *Top-ranking at the end of the previous season. †Members of the teams in the beginning of the season were invited to participate. M, male; F, female.

ities, after a competition season. They included cross country skiers (repetitive loading to upper and lower extremities), swimmers (repetitive loading to upper extremities without impact loads), long-distance runners (repetitive loading to lower extremities) and soccer players (high risk for impact loads and sprains). A sport injury questionnaire was sent to 300 top-ranking at the end of the previous season cross country skiers, 268 swimmers, 265 long-distance runners and 367 soccer players (21 teams). The inclusion and exclusion criteria used are shown in Fig. 1.

Questionnaire

The 12-month retrospective sport injury questionnaire was mailed to the above-mentioned groups of athletes. The questionnaire included items on anthropometry, training history, training and competition volume as well as on acute and overuse sport injuries during the past 12-month period. In addition, questions were asked about injury location, date of injury, the type of exercise that caused the acute injury and injury-related possible adverse effects on sport performance. The structural questionnaire also included details of the five most severe acute and overuse injuries sustained during the past 12 months. There was also a question asking whether there had been previous acute or overuse injuries in the same anatomic location injured during the past 12 months. Absence times because of acute and overuse injury from training or competition in the past 12 months were also inquired. The questionnaire included separate items on training hours and frequency per week during training and competition seasons as well as on the training and the competition season length. On the basis of these four questions, the total number of training hours per year was calculated. Injury rates are reported as number of injuries per 1000 exposure hours, i.e. any type of exercise and competition hours combined. The injury rates were calculated separately for acute, overuse and all injuries. The self-reported questionnaire data were validated and reliability-tested against interview data in 50 athletes from different sports in a week after filling the questionnaire (Karhula & Pakkanen, 2005; Eloranta & Tittonen, 2006). In addition, to investigate the reasons for not responding, we sent a one-page questionnaire to long-distance runners (99 athletes) who did not respond to our long questionnaire. The most commonly reported reason for non-response was the length of the questionnaire.

The term acute injury was defined as follows: an acute sports injury occurs suddenly or accidentally, interrupting the exercise or the competition of the athlete or causing an identifiable trauma. An acute injury is any physical injury that keeps the athlete away from at least one training session, or competition, or needs a physician's care. The term overuse injury was defined as follows: an injury causes pain during exercise loading without any noticeable external cause of injury. The injury gradually causes worsening pain during or after exercise. Pain becomes worse when loading is continued and may stop exercise completely. Minor injury was defined as time loss from training and competition from no time loss to 6 days and major injury as time loss from training and competition over 3 weeks. Time loss was defined as the time athletes were not able to participate in training or competition or the athlete needed medical care.

In addition, it was asked whether any injury during the past 12 months was the reason for quitting competitive sports. In spring 2007, we also interviewed by phone with a structural questionnaire those athletes (19 of 27, 70.4%) who had reported that they had quit sports because of an injury (injury was either the main reason or had an influence on the decision).

Statistical analysis

Statistical analyses were performed with SPSS (version 13.0; SPSS Inc., Chicago, Illinois, USA). χ^2 statistics, *t*-tests and analysis of variance were applied to calculate statistical differences in distributions between the different sports. A statistically significant threshold was accepted at $P \leq 0.05$, two-tailed. In *post hoc* between-group comparisons the Bonferroni correction was used.

Results

The response rate was 59% (639/1075). Of those athletes who returned the questionnaire 6% (65/1075) refused to participate. The final study group consisted of 574 elite athletes (149 cross country skiers, 154 swimmers, 143 long-distance runners and 128 soccer players) (Fig. 1). The subjects' characteristics are shown in Table 1.

Individual sport athletes responded better than soccer players and there was a variation in the response rates between soccer teams. The average age of the athletes who answered and who did not was the same. The response rate was higher in female (65.6%) than in male (53.8%) athletes ($P<0.001$).

The numbers of subjects in each sport with acute injuries are shown in Table 2. The number of subjects with acute injuries was the highest in soccer (73%, $P<0.001$) compared with the other sports (28–32%). The only statistically significant group difference in the occurrence of overuse injuries was between the long-distance runners and the soccer players (59% vs 42%, $P=0.005$) (Table 2). The overall (acute and overuse) incidence of injury can be seen in Table 2.

Among those athletes who had an acute injury, a higher proportion of long-distance runners (90%) reported at least one acute injury in the lower extremities compared with swimmers (61%, $P=0.002$) (Fig. 2a). Among those injured athletes, acute injuries in the upper extremities were more prevalent in the swimmers (45%) than cross country skiers, (15%, $P=0.002$), soccer players (12%, $P<0.001$) or long-distance runners (2%, $P<0.001$). The most typical location of acute injuries can be seen in Fig. 2a.

Swimmers reported overuse injuries in the shoulder more commonly than cross country skiers (40% vs 1%, $P<0.001$). Among the athletes with an overuse injury, long-distance runners (95%) had more overuse injuries in the lower extremities than the swimmers (33%, $P<0.001$), soccer players (78%, $P=0.002$) or cross country skiers (80%, $P=0.003$) (Fig. 2b). Among the long-distance runners who had at least one overuse injury, every fifth overuse injury ($n=17/85$) was located in the Achilles tendon. The proportion of athletes with at least one overuse injury (Fig. 2b) or all injuries by anatomical location is shown in Fig. 2c.

Compared with soccer players (67%), acute injuries during competitions were significantly less common in the cross country skiers (27%, $P<0.001$),

Table 1. Characteristics of the athletes, mean (SD)

	Cross country skiing ($n=149$)	Swimming ($n=154$)	Long-distance running ($n=143$)	Soccer ($n=128$)
Age (years)	22.7 (4.4)	18.7 (2.9)	24.3 (5.3)	22.0 (3.8)
Height (cm)	173.3 (8.2)	176.4 (9.1)	172.9 (8.8)	174.7 (9.7)
Weight (kg)	65.4 (9.3)	69.8 (11.3)*	59.8 (8.9)	70.2 (10.6)*
Body mass index (kg/m^2)	21.7 (1.6)	22.3 (2.1)*	19.9 (1.5)	22.9 (1.7)*
Start training (age)	7.6 (3.1)*	8.0 (2.2)	12.2 (4.8)†	7.0 (2.1)
Training years (at least 2 times/week)	11.6 (4.5)*	9.9 (3.1)*	10.4 (5.1)	13.8 (3.8)
Training hours in a year (hours/year, all kind of exercise)	552.7 (153.6)†	767.0 (323.8)‡	548.7 (251.6)‡	511.9 (219.8)‡
Kilometers per year (km/year)				
Skiing	2994.8 (1077.0)§			
Swimming		1500.8 (672.0)‡		
Running			3216.0 (1677.6)§	

*Data were missing for <1.0% of responders.
†Data were missing for 1–5.0% of responders.
‡Data were missing for 5–10.0% of responders.
§Data were missing for 10–15.0% of responders.

Table 2. Injury rate of the different sport groups in past 12 month

	Cross country skiing ($n = 149$)			Swimming ($n = 154$)			Long-distance running ($n = 143$)			Soccer ($n = 128$)		
	n	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI
Acute injuries												
No. of injured athletes (*n*)	41	(27.5)	21.0–35.2	49	(31.8)	25.0–39.5	41	(28.7)	21.9–36.6	94	(73.4)*	65.2–80.3
No. of athletes with two or more injuries (*n*)	15/41	(36.6)	23.6–51.9	24/49	(49.0)	35.6–62.5	18/41	(43.9)	29.9–59.0	63/94	(67.0)†	57.0–75.7
No. of injuries (*n*)	65			93			67			207		
Injuries per 1000 exposure hours (*n*/1000 h)	0.73			1.10			1.01			3.37‡		
Overuse injuries												
No. of injured athletes (*n*)	74	(49.7)	41.7–57.6	79	(51.3)	43.5–59.1	85	(59.4)§	51.2–67.1	54	(42.2)	34.0–50.8
No. of athletes with two or more injuries (*n*)	29/74	(39.2)	28.9–50.6	28/79	(35.4)	25.8–46.4	32/85	(37.6)	28.1–48.3	15/54	(27.8)	17.6–40.9
No. of injuries (*n*)	110			117			125			81		
Injuries per 1000 exposure hours (*n*/1000 h)	1.35			1.48			1.67			1.69		
All injuries												
No. of injured athletes (*n*)	93	(62.4)	55.7–68.7	99	(64.3)	57.7–70.4	107	(74.8)	68.4–80.3	109	(85.2)	79.2–89.6
No. of athletes with two or more injuries (*n*)	52/93	(55.9)	47.4–64.1	52/99	(52.5)	44.3–60.6	56/107	(52.3)	44.4–60.1	82/109	(75.2)	67.8–81.4
No. of injuries (*n*)	175			210			192			288		
Injuries per 1000 exposure hours (*n*/1000 h)	2.10			2.64			2.79			5.12¶		

*Injury rate higher ($P<0.001$) compared with other sports.

†Injury rate higher ($P=0.001$) compared with cross country skiers ($P=0.012$) compared with long-distance runners ($P=0.036$) compared with swimmers.

‡Injury rate higher ($P<0.001$) compared with other sports.

§Injury rate higher ($P=0.005$) compared with soccer players.

¶Injury rate higher ($P<0.001$) compared with cross country skiers ($P=0.001$) compared with long-distance runners ($P=0.010$) compared with swimmers.

95% CI, 95% confidence interval for the injured athletes and athletes with two or more injuries.

long-distance runners (15%, $P<0.001$) and swimmers (12%, $P<0.001$).

Of the acute injuries of the cross country skiers, 80% occurred in events other than skiing, and over one-third (35%) of their acute injuries occurred while running. In the swimmers 58% and in the long-distance runners 51% of the acute injuries occurred in events other than their own. Cross country skiers reported 61% of all overuse injuries originating in sport events other than cross country skiing, whereas 81% of the swimmers' overuse injuries were sustained while swimming.

The number of acute injuries and the number of previous injuries at the corresponding anatomical location are shown in Table 3. In cross country skiers and in soccer players the most common anatomical site of the recurrent acute injury was the ankle, in swimmers it was the back and in runners it was the foot. In case of overuse injuries, the most prevalent previous injury locations in skiers were the knee and foot, in swimmers the shoulder region, in runners it was the foot and in soccer players the back (Table 3).

Among the injured athletes the average time of non-attendance of training and competition during the past 12 months because of acute injury was significantly longer in the soccer players (56 days/year) than that in the cross country skiers (17 days/year, $P=0.001$) and in the swimmers (12 days/year, $P<0.001$). The long-distance runners (44 days/year) had more absence days than the cross country skiers ($P=0.019$) and the swimmers ($P=0.004$). Rather similar trends were seen in the absence times because of overuse injury (Table 4). The acute and overuse injuries together caused over a 3-month time loss of training and competition most commonly among the soccer players (26% and 19%, respectively) and the runners (17% and 22%, respectively) (Table 4).

Fifty-two (9.1%) athletes, 40 female and 12 male athletes ($P=0.001$) quit competitive sports during the 12-month period. Seven (13.5%) of them reported that the main reason for ending the sports career was a sports injury, and all of them were women. Twenty of 28 athletes whose decision to quit sports was influenced by an injury reported that the injury caused mild or moderate permanent disability. Among these athletes, three of four skiers reported that the decision to quit a sports career was due to an overuse injury, five of eight swimmers reported a shoulder injury and in soccer players six of seven reported a knee injury as having an influence on the decision to quit sports.

Discussion

The most important findings of the present study include that type of loading is strictly associated with the anatomical location of an overuse injury and that in some sports many injuries occur in sports other than the main event. The number of subjects with at least one acute injury was the highest in the soccer players, and the incidence of overuse injuries was the highest in the long-distance runners. Interestingly, among the cross country skiers both acute and overuse injuries occurred mainly in exercise other than their own event. Moreover, acute injuries in the swimmers occurred mainly when practising another sport, while overuse injuries occurred mainly while swimming. Our 12-month retrospective study was designed to investigate acute and overuse injuries among athletes in sports with different loading patterns.

The anatomic distributions of overuse injuries in particular were influenced by the loading patterns of the specific sports studied. Swimmers had acute and overuse injuries in the shoulder region, and a high proportion of acute and overuse injuries were located in the lower extremities in cross country skiers, long-distance runners and soccer players. Among skiers and runners, the main injury location was the knee and the foot, including the Achilles tendon. Injured long-distance runners and soccer players were nearly 2 months absent from training because of acute or overuse injuries. All those athletes who quit their sport career due to an injury were women.

Expectedly, acute injuries were common in soccer. Our finding that half of the acute injuries in soccer players occurred in matches is also in line with earlier findings (Kujala et al., 1995; Tegnander et al., 2008). In the other sport groups, acute injuries in competitions were rare.

The literature exhibits conflicting opinions regarding the injury rate linked to the skating and classic techniques in cross country skiing (Butcher & Brannen, 1998; Bahr et al., 2004). In our study, overuse injuries of the low back sustained in skiing were more frequent when using the classic (59%) than the skating technique (12%) (results not shown in detail). Only 20% of acute injuries were skiing injuries, and two-third of the overuse injuries occurred while practising some sport other than skiing. This finding is in accordance with the study by Orava et al. (1985).

Fig. 2. (a) The proportion of athletes with at least one acute injury during the past 12 months by anatomical location: (1) injury rate in the back was higher in cross country skiers than in long-distance runners ($P = 0.005$) and in soccer players ($P = 0.009$). Injury rate was higher in swimmers ($P = 0.003$) than in soccer players. (2) Injury rate in the upper arm and shoulder was higher in swimmers than in cross country skiers ($P = 0.002$), long-distance runners ($P < 0.001$) and in soccer players ($P < 0.001$). (3) Injury rate in the forearm, elbow, palm, wrist and fingers was higher in swimmers than in long-distance runners ($P = 0.010$) and in soccer players ($P = 0.023$). (4) Injury rate in the thigh was higher in soccer players than in cross country skiers ($P = 0.022$), in swimmers ($P = 0.006$) and in long-distance runners ($P = 0.048$). (5) Injury rate in the knee was higher in soccer players than in cross country skiers ($P = 0.009$). (6) Injury rate in the ankle was higher in soccer players than in swimmers ($P = 0.002$) and in long-distance runners ($P = 0.014$). (7) Injury rate in the foot was higher in long-distance runners than in swimmers ($P = 0.002$), in soccer players ($P = 0.002$) and in cross country skiers ($P = 0.018$). (b) The proportion of athletes with at least one overuse injury during the past 12 months by anatomical location: (1) injury rate in the back was higher in soccer players ($P = 0.002$), in cross country skiers ($P = 0.005$) and in swimmers ($P = 0.027$) than in long-distance runners. (2) Injury rate in the upper arm and shoulder was higher in swimmers than in cross country skiers ($P < 0.001$) in long-distance runners ($P < 0.001$) and in soccer players ($P < 0.001$). (3) Injury rate in the forearm, elbow, palm, wrist and fingers was higher in cross country skiers ($P = 0.009$) and in swimmers ($P = 0.022$) than in long-distance runners, and higher in cross country skiers than in soccer players ($P = 0.047$). (4) Injury rate in the hip, groin, buttock and pelvis was higher in long-distance runners ($P = 0.005$), in cross country skiers ($P = 0.038$) and in soccer players ($P = 0.041$) than in swimmers. (5) Injury rate in the thigh was higher in long-distance runners ($P = 0.007$) and in soccer players ($P = 0.013$) than in swimmers. (6) Injury rate in the calf was higher in cross country skiers ($P < 0.001$), in long-distance runners ($P < 0.001$) and in soccer players ($P = 0.005$) than in swimmers. (7) Injury rate in the foot was higher in cross country skiers ($P < 0.001$), in long-distance runners ($P < 0.001$) and in soccer players ($P < 0.001$) than in swimmers. Injury rate was higher in long-distance runners than cross country skiers ($P = 0.021$). (c) The proportion of athletes with at least one acute or overuse injury during the past 12 months by anatomical location: (1) injury rate in the head, neck and face was higher in soccer players ($P = 0.008$) and in swimmers ($P = 0.019$) than in long-distance runners. (2) Injury rate in the back was higher in cross country skiers ($P = 0.003$) and in swimmers ($P = 0.004$) than in long-distance runners. (3) Injury rate in the upper arm and shoulder was higher in swimmers than in cross country skiers ($P < 0.001$), long-distance runners ($P < 0.001$) and in soccer players ($P < 0.001$). (4) Injury rate in the forearm, elbow, palm, wrist and fingers was higher in swimmers than in long-distance runners ($P < 0.001$) and in soccer players ($P = 0.029$). Injury rate was also higher in cross country skiers than in long-distance runners ($P = 0.001$). (5) Injury rate in the hip, groin, gluteals and pelvis was higher in long-distance runners ($P = 0.002$), in soccer players ($P = 0.015$) and in cross country skiers ($P = 0.044$) than in swimmers. (6) Injury rate in the thigh was higher in soccer players than in cross country skiers ($P < 0.001$), in swimmers ($P < 0.001$) and in long-distance runners ($P = 0.003$), injury rate was higher in long-distance runners than in swimmers ($P = 0.039$). (7) Injury rate in the knee was higher in soccer players than in long-distance runners ($P = 0.050$). (8) Injury rate in the calf was higher in cross country skiers ($P = 0.001$), in long-distance runners ($P = 0.003$) and in soccer players ($P = 0.006$) than in swimmers. (9) Injury rate in the ankle was higher in soccer players than in swimmers ($P < 0.001$), in long-distance runners ($P < 0.001$) and in cross country skiers ($P = 0.002$). (10) Injury rate in the foot was higher in long-distance runners than in swimmers ($P < 0.001$), in soccer players ($P = 0.001$) and in cross country skiers ($P = 0.011$). Injury rate in soccer players and cross country skiers was higher than in swimmers ($P < 0.001$).

In previous studies, the occurrence of shoulder injury over 1 year in swimmers varied from 26% to 35% (Bak & Magnusson, 1997; McMaster et al., 1998). A swimmer performs more than one million strokes annually with each arm. Over 90% of the propulsive force comes from the upper extremities (Richardson, 1987; Pink & Tibone, 2000). In both swimming and skiing, the upper extremities are predisposed to repetitive loading, but,

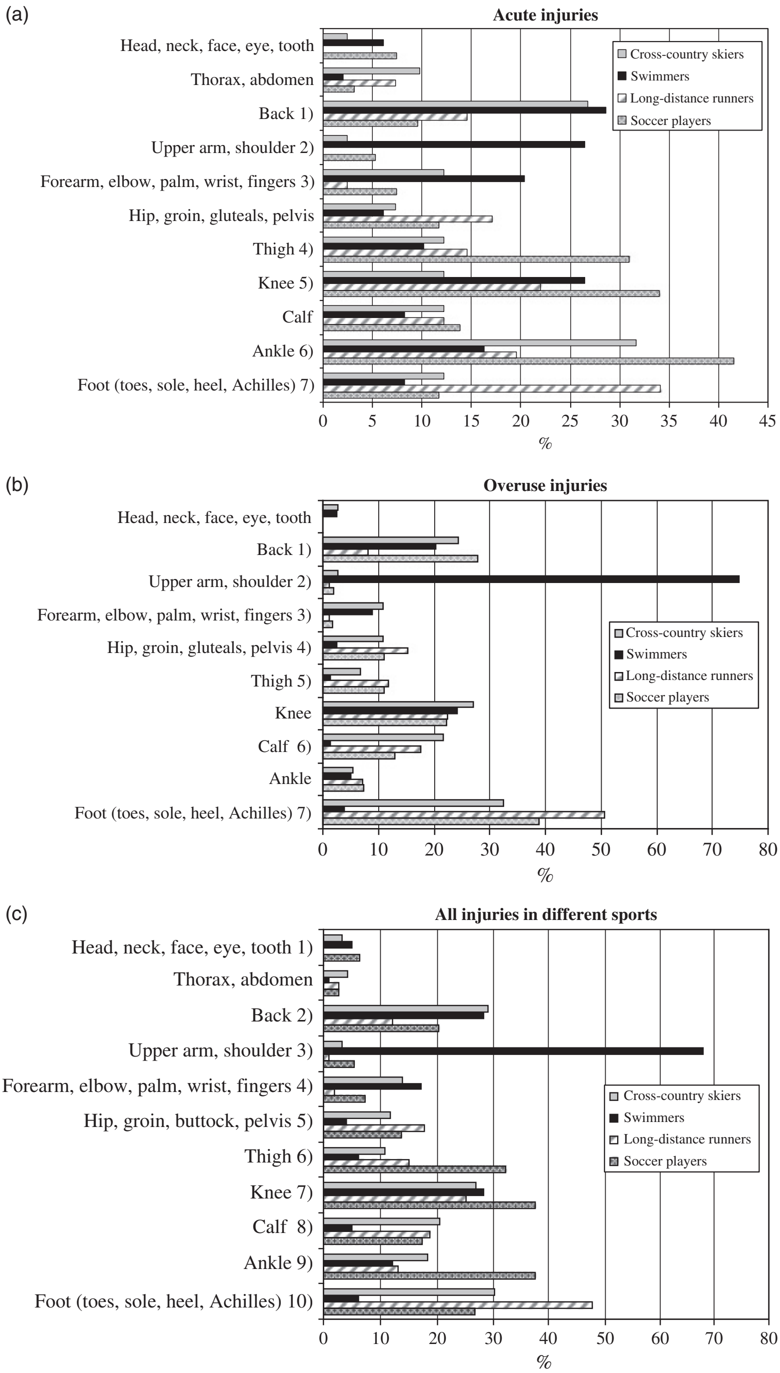

Table 3. Recurrence of acute and overuse injuries in the same anatomical site in different sport

	Cross country skiing $n=149$		Swimming $n=154$		Long-distance running $n=143$		Soccer $n=128$	
	Injury *n*	Previous Injury % (*n*)	Injury *n*	Previous Injury % (*n*)	Injury *n*	Previous Injury % (*n*)	Injury *n*	Previous Injury % (*n*)
Acute injuries								
Head, neck, face, eye, tooth	1	0 (0)	3	67 (2)	0	0 (0)	8	13 (1)
Thorax, abdomen	4	0 (0)	1	100 (1)	3	67 (2)	3	0 (0)
Back (low back+upper back)	11	72 (8)	16	56 (9)	6	17 (1)	9	33 (3)
Upper arm, shoulder	1	100 (1)	14	29 (4)	0	0 (0)	5	0 (0)
Forearm, elbow, palm, wrist, fingers	6	33 (2)	13	46 (6)	1	0 (0)	7	14 (1)
Hip, groin, gluteals, pelvis	3	0 (0)	4	75 (3)	8	50 (4)	13	31 (4)
Thigh	6	50 (3)	5	20 (1)	6	33 (2)	33	36 (12)
Knee	5	40 (2)	15	33 (5)	9	33 (3)	41	29 (12)
Calf	5	0 (0)	4	25 (1)	5	20 (1)	15	20 (3)
Ankle	16	50 (8)	8	13 (1)	10	50 (5)	46	46 (21)
Foot (toes, heel, Achilles, sole)	7	43 (3)	4	50 (2)	15	33 (5)	14	36 (5)
Total	65	42 (27)	87	43 (37)	63	37 (23)	194	32 (62)
Overuse injuries								
Head, neck, face, eye, tooth	2	0 (0)	2	100 (2)	0	0 (0)	0	0 (0)
Back (low back+upper back)	18	44 (8)	17	59 (10)	7	43 (3)	16	38 (6)
Upper arm, shoulder	2	50 (1)	61	62 (38)	1	100 (1)	1	0 (0)
Forearm, elbow, palm, wrist, fingers	8	13 (1)	7	43 (3)	1	100 (1)	1	0 (0)
Hip, groin, gluteals, pelvis	8	25 (2)	2	50 (1)	15	53 (8)	5	40 (2)
Thigh	5	20 (1)	1	0 (0)	10	20 (2)	9	11 (1)
Knee	21	33 (7)	19	42 (8)	21	24 (5)	13	0 (0)
Calf	16	50 (8)	1	100 (1)	15	60 (9)	7	14 (1)
Ankle	4	50 (2)	4	0 (0)	6	17 (1)	5	20 (1)
Foot (toes, heel, Achilles, sole)	24	29 (7)	3	33 (1)	52	33 (17)	23	22 (5)
Total	108	34 (37)	117	55 (64)	128	37 (47)	80	20 (16)

Table 4. Time loss from training and competition in different sport groups in past 12 month

	Time loss from training and competition, % (*n*)			
	Cross country skiers	Swimmers	Long-distance runners	Soccer players
Acute injury				
Injured athletes	41	49	41	94
Minor injury (total)	49 (20)	65 (32)	34 (14)	12 (13)
No time loss	12 (5)	27 (13)	2 (1)	1 (1)
1–3 days	22 (9)	25 (12)	12 (5)	6 (6)
4–6 days	15 (6)	14 (7)	20 (8)	6 (6)
Moderate injury (1–3 weeks)	32 (13)	25 (12)	20 (8)	30 (28)
Major injury (total)	19 (8)	10 (5)	46 (19)	56 (53)
>3 weeks<3 months	17 (7)	6 (3)	29 (12)	31 (29)
>3 months<6 months	0 (0)	4 (2)	12 (5)	16 (15)
>6 months	2 (1)	0 (0)	5 (2)	10 (9)
Overuse injury				
Injured athletes	74	79	85	54
Minor injury (total)	66 (49)	62 (49)	23 (20)	33 (18)
No time loss	38 (28)	38 (30)	13 (11)	19 (10)
1–3 days	18 (13)	13 (10)	7 (6)	4 (2)
4–6 days	11 (8)	11 (9)	4 (3)	11 (6)
Moderate injury (1–3 weeks)	22 (16)	25 (20)	25 (21)	26 (14)
Major injury (total)	12 (9)	13 (10)	52 (44)	41 (22)
>3 weeks<3 months	11 (8)	8 (6)	29 (25)	22 (12)
>3 months<6 months	1 (1)	5 (4)	14 (12)	9 (5)
>6 months	0 (0)	0 (0)	8 (7)	9 (5)

interestingly, overuse injuries in the upper extremities were common only in swimmers and were sustained while swimming. This is probably related to the overhead movements performed by swimmers.

The occurrence of injuries over 1 year among the long-distance runners was 75% (overall injury), which was somewhat greater than that found in previous studies (48–57%) (Lysholm & Wiklander, 1987; Walter et al., 1989). But then, the number of runners with knee injuries in our study was lower than has been reported earlier (van Mechelen, 1992; Duffey et al., 2000; van Gent et al., 2007). However, runners had a high number of Achilles tendon injuries, a finding that is supported by Rolf (1995). A high risk for Achilles tendinopathy and tendon rupture in former runners and master track and field athletes has been reported (Kujala et al., 2005; Kettunen et al., 2006).

We found that there was a previous injury in the same anatomic location in 36% of acute injuries and 38% of overuse injuries when all sports were combined. Expectedly, recurrence of injuries was common in locations where the incidence of new injuries is common. This knowledge is important when rehabilitating injuries in these locations. These recurrent injuries were especially common in swimmers and the rarest in soccer players. Previously, the proportion of recurrent injuries in soccer during three seasons has been reported to be over 20% (Hawkins & Fuller, 1999). In our study, the amount was nearly 30%. The difference may be partly explained by methodological differences between the studies. Almost twice more of our long-distance runners reported a previous injury than in the previous study by Marti et al. (1988). These differences may at least partly be explained by the fact that training volume among participants in the study of Marti et al. (1988) may have been lower than in our study.

Chomiak et al. (2000) and Tegnander et al. (2008) reported in soccer players that 17% of injuries were severe and require over 4 weeks of time loss from the sport. In our soccer players, the corresponding proportions were much higher for both acute (38%) and overuse injuries (29%). This may be because of a high number of acute knee and ankle injuries with a long time loss in our study. In long-distance runners, time loss was common because of overuse tendon injuries; mainly, the injuries were in the Achilles tendon, causing nearly 2 months absence from training and competition. Although swimmers had a great number of injuries, long-term time loss was rare.

In our soccer players, the knee injury was the most common cause ending the sport career, especially in women. According to the male Finnish former elite athlete cohort (Kettunen et al., 2001), 20% reported that they had quit their sports career due to sports injury, and in a large case-series of Finnish athletes knee injury was the most common reason causing mild degree permanent disability (Kujala et al., 1995). In the present study, none of the athletes reported severe permanent disability due to sports injury but injuries caused mild disabilities and long time losses from training and seven quit sports because of injury. This has high importance for athletes and may possibly prevent participation in leisure physical activity in later life (Kujala et al., 2003).

Type of sport is related to injury profile

Sport-related injury risk has been reported in varying ways (van Mechelen, 1992; Hunter, 1999; Junge & Dvorak, 2000; Rauh et al., 2006), which makes it difficult to compare the results of different studies. For the most part, earlier studies have reported all sport-related injuries but not separated acute from overuse injuries. With respect to their etiology and possible means of prevention, differentiation between acute and overuse injuries would seem to be essential. It is clinically important that sports-specific analyses are performed to determine the risk factors for injuries typical to each sport to help in their prevention. Knowledge from our study can be used in injury prevention and in tailoring substitute training or rehabilitation programs to injured athletes.

The fairly low response rate in our study was comparable to that in other retrospective epidemiological sport injury studies (Maffulli et al., 2005; Rauh et al., 2006). One explanation for the low response rate may have been the length of our questionnaire (42 pages) as reported by long-distance runners in our short questionnaire to non-responders. The fairly low response rate of the soccer players might be due to the fact that we sent the questionnaire after the competition season when the members of each team were resting from training and competition. Female athletes responded more actively than male athletes. Overall, we did not find an association between the position in the ranking list and the response rate. However, we do not have exact knowledge on whether those who did not respond had fewer injuries, but this possible selection bias should be rather similar in all sports.

Outcomes may also be influenced by the method of data collection. Walter and Hart (1990) reported that retrospective surveys are less likely to provide accurate incidence data because they rely on athletes' responses and on diagnoses that lack verification by a physician. In our study, the self-reported questionnaire data were validated and reliability-tested against interview data, and were shown to be accurate (Karhula & Pakkanen, 2005; Eloranta & Tittonen, 2006). In addition, elite athletes usually keep a training diary, which can be expected to improve the accuracy of the questionnaire data collection. Comparability between different sports should not be a problem in our study as the method applied was the same for all the four sports studied. However, retrospective data collection is a limitation in our study. Also, the validation method we used does not exactly reveal the accuracy and coverage of the reported injuries, but was more adequate for measuring the reproducibility/repeatability of the data collection. Retrospective survey studies have two main categories of recall bias (Harel et al., 1994): a memory decay, which means the loss of information due to failure to recall the event, and the telescoping effect, which is the tendency to remember events in the past as if they occurred closer to the present than they actually did. Survey studies do not always underestimate injury incidence, since some common injuries may be overreported (Peterson et al., 1993).

In conclusion, acute injuries among cross country skiers and swimmers occurred mainly in sport other than their own event. Both swimmers and cross country skiers use the upper extremities and especially shoulders, but shoulder injuries were less common in cross country skiers compared with swimmers. The number of acute injuries was high in soccer players while overuse injuries were most common among long-distance runners.

Perspectives

In addition to costs to health care, numerous injuries caused by sport result in time loss from training and competition. Although injuries are not usually severe from the medical point of view, their importance for active athletes is high. Different types of studies have been carried out to identify the injury profiles and their etiological background. However, rather little epidemiological research is available differentiating acute and over-use injuries and comparing different types of sport using the same methodology. Our study shows that to understand the etiology of sports injuries and to find out ways of preventing them, acute and overuse injuries need to be differentiated in the analyses. Acute injuries often occur in contact situations and among endurance athletes in sports other than their own sports event. Overuse injury occurrence is anatomically strictly linked to the specific loading patterns of each sport. In our study, no severe permanent disabilities occurred due to injury but seven women reported having quit sports because of an injury, which area needs further studies. The knowledge derived from our study can be used in the prevention of injuries and in tailoring substitute training or rehabilitation programs to physically active individuals.

Key words: athletic injuries, overuse, incidence, epidemiology.

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II

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Gender differences in sport injury risk and types of injuries: a retrospective twelve-month study on cross-country skiers, swimmers, long-distance runners and soccer players

by

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Research article

Gender differences in sport injury risk and types of injuries: a retrospective twelve-month study on cross-country skiers, swimmers, long-distance runners and soccer players

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Abstract
This twelve months survey compared injury risk and injury types by genders (312 females, 262 males) in 15- to 35-year-old cross-country skiers, swimmers, long-distance runners and soccer players. More male than female athletes reported at least one acute injury (44% vs. 35%, $p < 0.05$), and more male than female runners reported at least one overuse injury (69% vs. 51%, $p < 0.05$). When the incidence of acute and overuse injuries both separately and combined was calculated per 1000 training hours, per 1000 competition hours and all exposure hours combined we found no gender differences in either of these comparisons. After adjustment for sport event males were at increased risk for posterior thigh overuse injuries compared to females (relative risk (RR) 5.8, 95% confidence interval (CI) 1.3 to 26.4, $p < 0.05$) while females were at increased risk for overuse injuries in the ankle compared to males (RR 3.1, 95% CI 1.0 to 9.3, $p < 0.05$). After adjustment for exposure time (injuries/1000 exposure hours) significance of the difference between the sexes in overuse injury to the ankle persisted (female 0.11 vs. male 0.02 injuries/1000 exposure hours, $p < 0.05$). Six athletes had an anterior cruciate ligament (ACL) injury, of whom four were female soccer players. After combining all reported acute and overuse ankle and knee injuries, the proportion of athletes with such injury was higher in the female compared to male soccer players (75% and 54% respectively; $p < 0.05$), but no difference was found in such injuries when calculated per 1000 exposure hours. In conclusion, we found some gender differences in sport-related injuries, but most of these differences seemed to be explained at least in part by differences in the amount of training.

Key words: Male, female, athletic injuries, acute injury, overuse injury.

Introduction

In general patterns of injuries in athletes have been assumed to be more sport-specific than gender-specific. Presently, most sport injury studies that have investigated gender differences have focused exclusively on knee injuries (Arendt and Dick, 1995; Dugan, 2005). To date, only a few sport injury studies have compared acute injury rates (Kujala et al., 1995) or overall injury rates (de Loes et al., 2000; Sallis et al., 2001) between the sexes.

Previous studies have found similar overall injury rates in men and women (Lanese et al., 1990; Sallis et al., 2001). In contrast some sports and recreation-related injury studies have shown male athletes to be at greater risk for injury than their female counterparts (Conn et al., 2003; Dempsey et al., 2005). Powell and Barber-Foss (2000) and Elias et al. (2001) have reported that female soccer players had a higher incidence of injury than males.

Male athletes have been reported to have a higher risk for severe sport-related injuries than female athletes (Conn et al., 2003). Only a few studies have reported on gender differences in injuries related to cross-country skiing (Sandelin et al., 1980) and swimming (McMaster and Troup, 1993).

Specific to body location, females athletes have been reported to have more injuries to the hip (Sallis et al., 2001; Satterthwaite et al., 1999), lower leg and shoulder than male athletes, while males had more injuries in the thigh than females (Sallis et al., 2001). In marathon runners Satterthwaite et al. (1999) noticed that males had greater risk for hamstring and calf injuries than female runners. de Loes et al. (2000) reported that overall risk for knee injury in 12 sports was significantly higher for females than males. Similarly Arendt and Dick (1995) found that knee injuries were more prevalent among female than male soccer players.

Overall, the literature of gender differences in injuries is limited. It is not known precisely whether the gender differences found are sport-specific only and thus related to training behaviors, or whether the difference in risk is related to biological gender differences.

Our purpose was to study differences in sport-related injuries between male and female elite athletes in four sports with different loading patterns. The sports were cross-country skiing, swimming, long-distance running and soccer.

Methods

Subjects

A questionnaire was sent to competitive top-ranking Finnish female and male athletes (age 15 - 35 years) after each competitive season. Overall, 1200 questionnaires were distributed with the sample represented four different sports and loading modalities for 300 cross-country skiers (repetitive loading to upper and lower extremities with pliant movements), 268 swimmers (repetitive loading to upper extremities without impact loads), 265 long-distance runners (repetitive loading to lower extremities with moderate impact loads) and 367 (21 teams) soccer players (higher for impact loads and sprains)

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Table 1. Anthropometrics and training data in four different sports. Data are means (±SD).

	CC skiing		Swimming		LD running		Soccer		Total	
	♂ (n = 62)	♀ (n =87)	♂ (n= 71)	♀ (n =83)	♂ (n = 67)	♀ (n = 76)	♂ (n = 62)	♀ (n = 66)	♂ (n = 262)	♀ (n = 312)
Age (years)	24.0 (4.1)	21.8 (4.3)*	19.0 (2.9)	18.3 (2.9)	25.3 (5.2)	23.5 (5.3)*	22.9 (3.0)	21.1 (3.8)*	22.7 (4.6)	21.2 (4.5)**
Height (m)	1.80 (.06)	1.68 (.05)**	1.84 (.07)	1.70 (.06)**	1.80 (.06)	1.67 (.05)**	1.83 (.06)	1.67 (.06)**	1.82 (.06)	1.68 (.06)**
Body weight (kg)	74.0 (6.1)	59.3 (5.5)**	78.8 (8.4)	62.0 (6.7)**	66.8 (6.6)	53.5 (5.1)**	78.8 (6.1)	62.1 (7.0)**	74.6 (8.5)	59.2 (7.0)**
BMI (kg·m^{-2})	22.8 (1.1)	20.9 (1.4)**	23.3 (1.8)	21.4 (1.9)**	20.6 (1.3)	19.2 (1.3)**	23.6 (1.2)	22.2 (1.8)**	22.6 (1.8)	20.9 (1.9)**
CMP (days/year)	43.9 (28.4)	34.5 (25.7)*	14.5 (15.6)	12.0 (10.9)	20.5 (25.0)	12.0 (19.1)*	11.4 (11.5)	18.0 (20.4)*	22.2 (24.4)	19.5 (21.9)
Compet. (n/year)	28.0 (7.7)	26.0 (8.5)	12.6 (6.6)	11.8 (5.4)	19.8 (11.4)	18.1 (11.8)	30.1 (13.4)	32.4 (14.3)	22.2 (12.2)	21.6 (12.7)
RestTR(days/week)	0.8 (0.5)	0.9 (0.4)	1.1 (0.6)	1.1 (0.3)	0.6 (0.6)	0.9 (0.5)**	1.3 (0.5)	1.4 (0.6)	1.0 (0.6)	1.1 (0.5)*
RestC (days/week)	1.2 (0.6)	1.2 (0.5)	1.4 (0.8)	1.2 (0.5)	0.9 (0.7)	1.3 (0.7)**	1.7 (0.5)	1.6 (0.5)	1.3 (0.7)	1.3 (0.6)
Start training (age)	7.4 (2.7)	7.8 (3.4)	8.0 (2.1)	8.0 (2.2)	11.7 (3.9)	12.6 (5.5)	6.2 (1.6)	7.8 (2.3)**	8.4 (3.4)	9.0 (4.1)
Tr years	12.9 (4.1)	10.7 (4.6)*	10.1 (2.9)	9.7 (3.2)	11.8 (5.3)	9.1 (4.7)*	15.1 (3.6)	12.5 (3.6)**	12.4 (4.4)	10.4 (4.3)**
Tr hours	594 (161)	522 (142)*	779 (340)	755 (309)	568 (283)	532 (220)	584 (262)	445 (144)*	636 (285)	566 (242)*
Compet. hours	17.4 (7.3)	10.1 (7.4)**	2.6 (12.8)	0.7 (1.3)	8.4 (9.5)	7.1 (8.0)	45.3 (20.1)	47.8 (21.7)	17.9 (21.0)	14.8 (20.7)

CC = Cross-country, LD = Long distance, BMI = body mass index, CMP = camping days, Compet. = competitions, RestTR = rest days during training season, RestC = rest days during competition season, Tr years = training years at least 2 times/wk, Tr hours = training hours in a year (hours/year, all kind of exercise), Compt. Hours = competition hours in a year.
* $p < 0.05$, ** $p < 0.001$ Differences are shown between male and female in each sport and all sports together.

The long-distance runners whose running distance was from 1500m to marathon were included in to the study. After excluding participants over 35 years of age and soccer teams with a low response rate, the final study target group consisted of 1075 athletes (Ristolainen et al., in press, 2009). The study protocol was approved by the ethics committee of the University of Jyväskylä.

Questionnaire

The 12-month structural retrospective sport injury questionnaire included items on anthropometry, training history, training and competition volume as well as on acute and overuse sport injuries during the past 12-month period. In addition, questions were asked about the anatomical location of the injury, type of injury and situation in which the injury was sustained (in training or competition). Female athletes were also asked about if the menstruation had begun, and in what age they started, the regularity or irregularity of menstrual cycle (oligo- or amenorrhea). The menstrual irregularity was defined as 6 menstruations or less per year or missing menstruation (Bennell and Alleyne, 2007). Also the number of menstrual cycles was asked during the past 12 months. The questionnaire has been previously validated against interview data (Eloranta and Tittonen, 2006; Karhula and Pakkanen, 2005).

The term acute injury was defined as an injury that occurs suddenly or accidentally, interrupting the athlete´s training or performing in a competition or causing an identifiable trauma. An acute injury was any physical injury which kept the athlete away from at least one training session, or competition, or needed a physician's care. The term overuse injury was defined as an injury that causes pain during exercise loading without any noticeable external cause of injury. The injury gradually caused worsening pain during or after exercise. The pain got worse when the loading was continued and might cause the exercise to be stopped completely.

Statistics

The statistical analyses were done with the Statistical Package for the Social Sciences, version 15.0 (Norusis/SPSS, Inc., Chicago, Illinois). We calculated the results as absolute injury rates, comparing between the sexes. We then calculated injury rates as number of injuries per 1000 exposure hours i.e. hours spent on any type of training or on performing in competitions separately and combined. Injury rates were calculated separately for acute, overuse and all injuries. χ^2 statistics, t tests and analysis of variance (ANOVA) were applied to calculate statistical differences in gender distributions and between sports. Poisson regression was used to calculate the injury risk, adjusted for sport event, between the sexes.

Results

Six hundred and thirty-nine out of 1200 (53%) returned a questionnaire, from which 574 (312 female and 262 male) agreed to participate to this study. Final participation

Table 2. Injuries and injury rates between men and women in four different sports during the past twelve-month period.

	CC skiing		Swimming		LD running		Soccer		Total	
	♂ (n = 62)	♀ (n =87)	♂ (n= 71)	♀ (n =83)	♂ (n = 67)	♀ (n = 76)	♂ (n = 62)	♀ (n = 66)	♂ (n = 262)	♀ (n = 312)
Acute injuries										
No of injuries (n)	24	41	54	39	36	31	111	96	225	207
No of injured athletes n (%)	16 (26)	25 (29)	27 (38)	22 (27)	21 (31)	20 (26)	52 (84)	42 (64)*	116 (44)	109 (35)†
No of injured athletes with two or more injuries n (%)	5 (31)	10 (40)	14 (52)	10 (46)	10 (48)	8 (40)	32 (62)	31 (74)	61 (53)	59 (55)
Injuries per 1000 exposure hours (n/1000h)	0.57	0.85	0.95	1.24	1.19	0.85	3.64	3.11	1.53	1.43
Overuse injuries										
No of injuries (n)	45	65	55	62	66	59	34	47	200	233
No of injured athletes n (%)	30 (48)	44 (51)	36 (51)	43 (52)	46 (69)	39 (51)‡	24 (39)	30 (46)	136 (52)	156 (50)
No of injured athletes with two or more injuries n (%)	13 (43)	16 (36)	12 (33)	16 (37)	16 (35)	16 (41)	5 (21)	10 (33)	46 (34)	58 (37)
Injuries per 1000 exposure hours (n/1000h)	1.19	1.46	0.97	1.92	1.89	1.48	1.18	2.14	1.31	1.73
All injuries										
No of injuries (n)	69	106	109	101	102	90	145	143	425	440
No of injured athletes n (%)	35 (57)	58 (67)	45 (63)	54 (65)	55 (82)	52 (68)	57 (92)	52 (79)§	192 (73)	216 (69)
No of injured athletes with two or more injuries n (%)	22 (63)	30 (52)	26 (58)	26 (48)	29 (53)	27 (52)	42 (74)	40 (77)	119 (62)	123 (57)
Injuries per 1000 exposure hours (n/1000h)	1.77	2.33	1.94	3.25	3.15	2.45	4.90	5.32	2.89	3.25

* Proportion of injured athletes with acute injuries was higher in male soccer players than in female players ($p < 0.01$). † Proportion of injured athletes with acute injuries was higher in male athletes than in female counterparts ($p < 0.05$). ‡ Proportion of injured athletes with overuse injuries was higher in male long-distance runners than female runners ($p < 0.05$). § Proportion of injured athletes with all injuries was higher in male soccer players than in female players ($p < 0.05$).

response rate was 48%. To investigate the reasons for not responding we sent one-page questionnaire to long-distance runners (99 athletes) who did not respond to our long questionnaire. The most common reported reason for non-response was the length of the questionnaire. Females reported less training (566 hours/year [h/yr]) during the past twelve months than males (636 h/yr, $p < 0.05$). The athletes reported on average 16.2 competition hours per year (female: 14.8 and male: 17.9, $p = 0.08$) for the whole sample. The average number of competition hours varied by sport because of different duration of competitions i.e. in swimmers vs. soccer players. Detailed sex-specific, anthropometric and training and competition information are shown in Table 1.

Acute injuries

Two hundred and twenty-five athletes (39%) reported 432 acute injuries. More male than female athletes reported an acute injury (44% vs. 35%, $p < 0.05$); this was especially seen in soccer players (84% vs. 64%, $p = 0.01$). However, after the acute injuries were calculated per 1000 exposure hours (training and competition hours combined), no gender differences were found (Table 2). Moreover, no gender difference was found in any specific sports in acute injuries sustained in a competition when calculated per 1000 competition hours.

There were only a few significant gender differences in what body locations acute injuries occurred. A higher proportion of female athletes than male athletes had an acute injury at the heel ($p < 0.05$). More male than female athletes had an acute injury in the upper back ($p < 0.05$). After adjustment for sport event these differences were no longer statistically significant. The locations of acute injuries by genders are shown in more detail in Figure 1.

A higher proportion of men than women reported an acute muscle injury (44% vs. 31%, $p < 0.05$). After adjustment for sport event the difference was no longer statistically significant. A higher proportion of female (46%) than male athletes (33%) reported an acute ligament injury ($p < 0.05$) (Figure 2); this was seen especially in soccer players (71% vs. 42%, $p < 0.01$).

Overuse injuries

Four hundred and thirty-three overuse injuries were sustained by 292 athletes (51%). Overuse injuries were more prevalent among male than female runners (69% vs. 51%, $p < 0.05$), but there was no statistical significant difference found when the overuse injuries were calculated per 1000 exposure hours (Table 2).

The specific anatomical locations of overuse injuries by gender are shown in Figure 3. A higher proportion of men than women reported an injury in the posterior thigh ($p < 0.01$). This was especially seen in soccer players ($p < 0.05$). After adjustment for

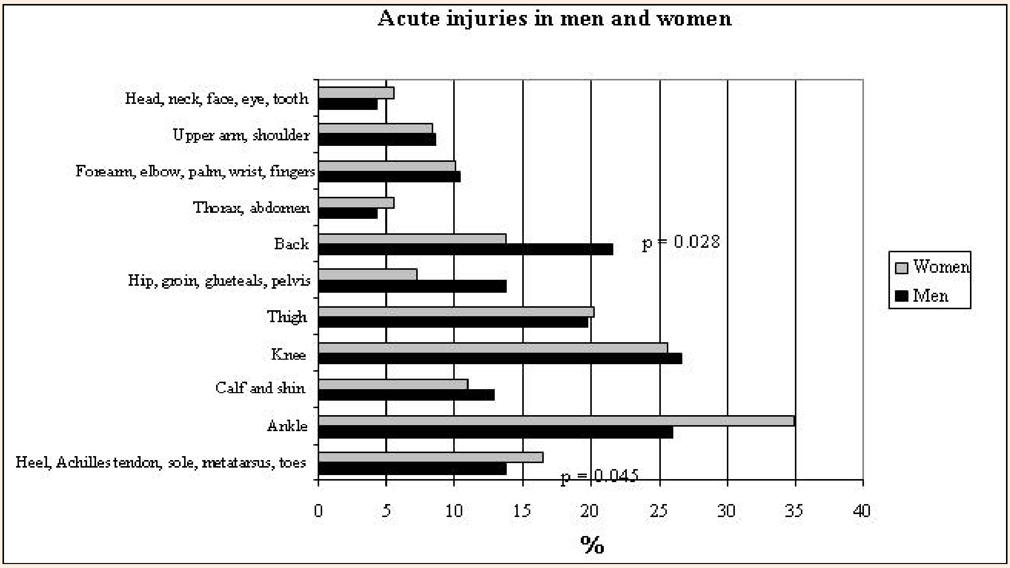

Figure 1. Location and proportions (%) of acute injuries by gender.
A higher proportion of female than male athletes had acute injury in the heel (6% vs. 1%, $p < 0.05$).
A higher proportion of male than female athletes had acute injury in the upper back (4% vs. 0 %, $p < 0.05$).

sport event male athletes were at increased risk for posterior thigh overuse injuries compared to female (RR 5.8, 95% CI 1.3-26.4, $p < 0.05$). In addition, more men than women reported toe ($p < 0.05$) and upper back ($p < 0.05$) injuries. A higher proportion of female than male athletes reported ankle ($p < 0.05$) injuries (Figure 3). After adjustment for sport event the risk for overuse ankle injury was greater in females than males (RR 3.1, 95% CI 1.0-9.3, $p < 0.05$). The ankle injury rate per 1000 exposure hours was also greater in female than male athletes (0.11 vs. 0.02, $p < 0.05$). A higher proportion of female than male cross-country skiers reported an overuse injury at

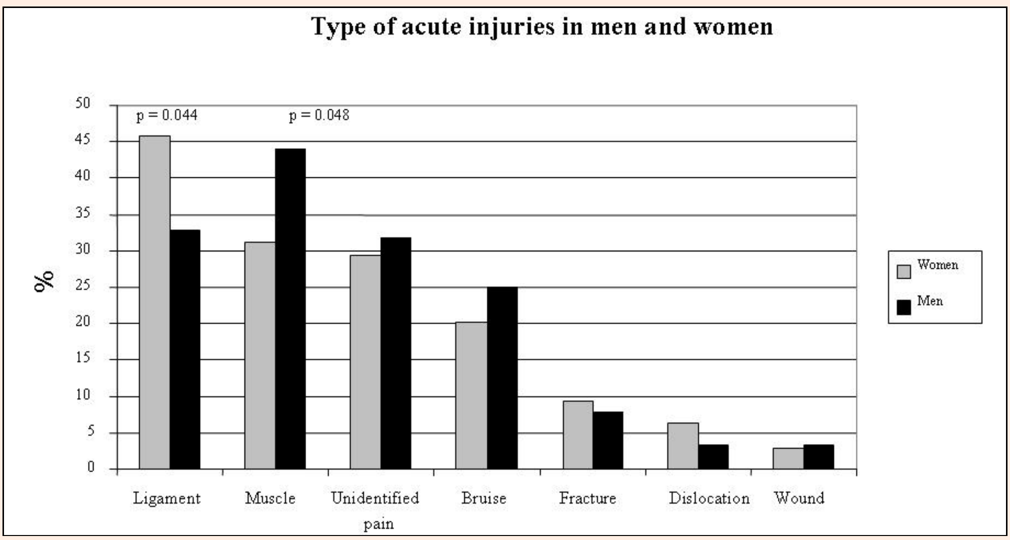

Figure 2. Proportion (%) of subjects with at least one acute injury in different tissues by gender.
A higher proportion of female than male athletes had ligament injuries (46% vs. 33%, $p < 0.05$).
A higher proportion of male than female athletes had muscle injuries (44% vs. 31%, $p < 0.05$).

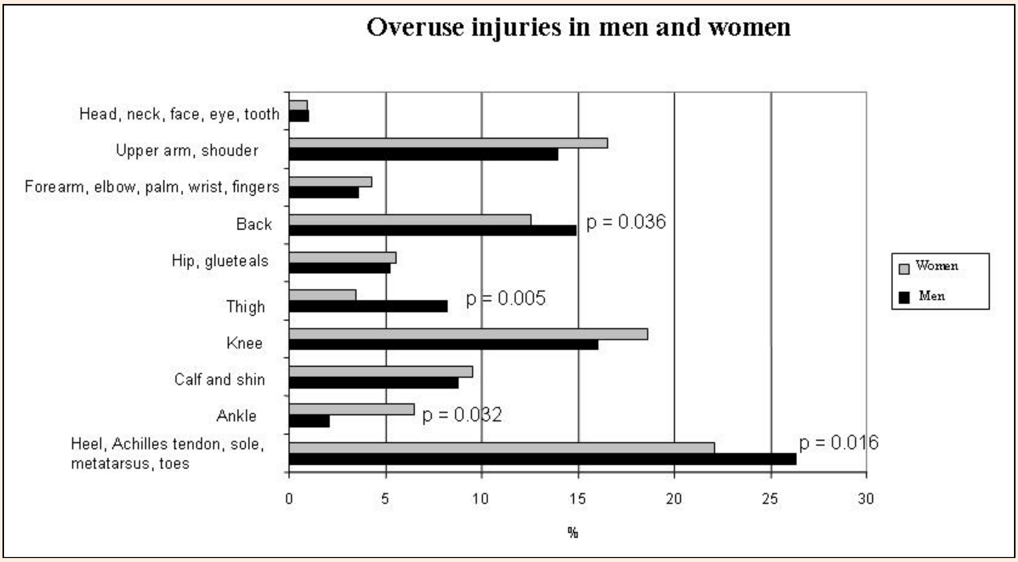

Figure 3. Location and proportions (%) of overuse injuries by gender.
A higher proportion of male than female athletes had overuse injuries in the posterior thigh (8% vs. 1%, $p < 0.01$), toe (4% vs. 0%, $p < 0.05$), and upper back (4% vs. 1%, $p < 0.05$). A higher proportion of female than male athletes had overuse injuries in the ankle (9% vs. 3%, $p < 0.05$).

the heel ($p < 0.05$), the injury rate being 0.14 in females and 0.0 in males per 1000 exposure hours ($p < 0.05$). There was found no gender differences in the proportion of overuse injuries by tissue type (Figure 4).

All injuries

A significantly higher proportion of male (92%) than female soccer players (79%, $p < 0.05$) reported at least one injury during the past twelve months. The same trend was found in long-distance runners, among whom 68% of female and 82% of male runners reported injury ($p = 0.06$ between the sexes).

When combining acute and overuse injuries of the ankle and the knee among all athletes, no difference was observed in the proportion of injured athletes between females (49%) and males (41%) ($p = 0.13$). After repeating the same analysis within sports between the sexes, the only significant difference was seen among soccer players. The proportion of female players with such an injury was higher than the proportion of male players (75% and 54% respectively; $p < 0.05$). In our study an anterior cruciate ligament (ACL) injury was identified in six cases,

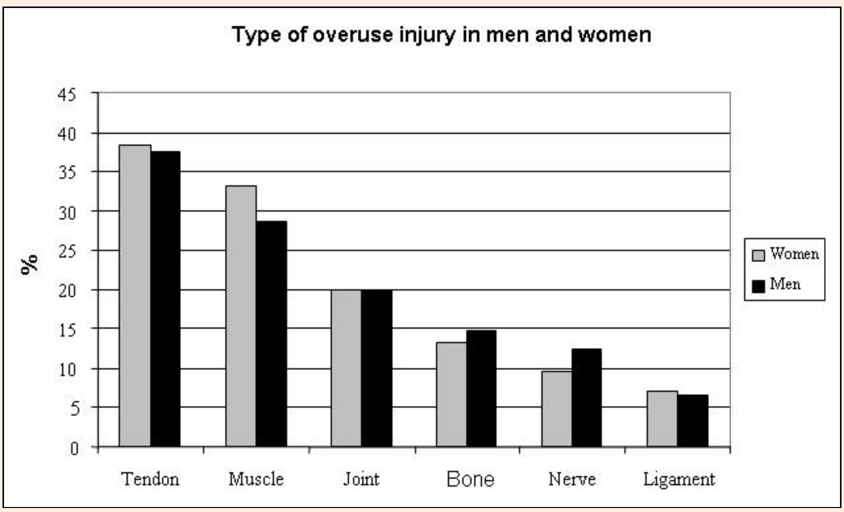

Figure 4. Proportion (%) of subjects with at least one overuse injury by tissue type and by gender.

four of which were women. Five of these ACL injuries occurred in soccer players and one female player had been injured twice.

Menstrual irregularities and injuries

Menstrual irregularities were reported by 40 (13%) women and were more common among long-distance runners (26%) than soccer players (6%, p = 0.002) or swimmers (6%, p = 0.001). Cross-country skiers (16%) reported menstrual irregularities more often than swimmers (6%, p = 0.05) and the same trend was seen also in soccer players (6%, p = 0.07). The only difference between athletes with regular and those with irregular menses was found in overuse injury among cross-country skiers (46% vs. 85%, p = 0.01).

Discussion

The primary goal of our study was to investigate gender differences in sport-related injuries during the previous twelve months in four sports with different loading patterns. More male than female athletes had at least one acute injury. Also more male than female long-distance runners had at least one overuse injury. However, when we calculated the incidence of acute or overuse injuries as the number of injuries per 1000 exposure hours, we found no gender differences. A few gender differences were observed in the anatomical location of injuries. The main difference was a greater number of overuse injuries in the posterior thigh in male than female athletes, whereas females had a greater risk for overuse injuries to the ankle. The risk for such injuries remained after adjustment for sport event. A higher proportion of female soccer players had more combined acute and overuse injuries in the ankle and knee than male players.

More acute injuries per year have been reported among male than female athletes (Kujala et al., 1995; Sandelin et al., 1980). Powell and Barber-Foss (2000) reported more acute injuries in girl than boy soccer players and Elias (2001) showed slightly greater aggregate injuries in female than male soccer players. In addition, increased injury risk in female than male for swimmers (Sallis et al., 2001) and high-school cross-country runners (Rauh et al., 2000) has been reported. Overall, in accordance with our findings, Lanese et al. (1990) found no differences in overall injury incidence in different sports after adjustment for exposure time. However, Rauh et al. (2006) found gender differences after adjusting exposure time. It seems that possible gender differences in the injury rate may be partly due to or explained by differences in exposure time.

In a review, van Gent et al. (2007) reported that injury rates in the lower extremities were common in both female and male runners. The same finding was reported for cross-country skiers (Sandelin et al., 1980; Orava et al., 1985), which is in line with our results. An equal number of overuse injuries of the lower limbs was also found between males and females in sports other than swimming. In contrast to Sallis et al. (2001) and Satterthwaite et al. (1999) we found no gender difference between different groups of sport in injuries in the calf or hip. Sallis et al. (2001) studied injuries among athletes at the intercollegiate level and Satterthwaite et al. (1999) studied injuries and other health problems during a marathon race. Differences in study design, such as definition of the injury or different data collection methods, may explain these conflicting results.

Hamstring strains are common injuries in sports characterized by maximal sprinting, kicking and sudden acceleration (Lysholm and Wiklander, 1987). Waldén et al. (2005) reported that acute thigh injury in soccer players was the most common injury, causing a great amount of training and competition time loss. There is evidence showing that previous hamstring strains and age (Arnason et al., 2004) are independent risk factors for new hamstring strains. Thigh injuries may partly be explained by muscle fatigue, high training intensities, insufficient warm-up and hamstring tightness (Kujala et al., 1997), but the evidence for this is less convincing (Arnason et al., 2004; Bahr and Holme, 2003). In some cases the number of players per soccer team may be low and therefore the high amount of playing time per player may increase the risk for thigh injuries, and also the risk for overall injuries. In our study there was no difference between the sexes in acute thigh injuries. However, a higher proportion of our male than female athletes had overuse injuries in the posterior thigh, which is in line with the findings of earlier studies (Satterthwaite et al., 1999; Sallis et al., 2001) and clinical experience. Hosea et al. (2000) found in basketball players that females had greater overall risk for ankle injury than males. In our study females had a three-fold greater risk than males for overuse injury in the ankle. Higher joint laxity in females may contribute to this finding (Rozzi et al., 1999; Quatman et al., 2008).

Similar to the study by McMaster and Troup (1993) on elite swimmers, in our swimmers overuse injuries occurred mostly in the shoulder region and no gender differences were found. Upper back injuries were rare in our female swimmers. Sallis et al. (2001) reported more injuries in college female than male swimmers in the shoulder and back/neck region. They suggested that a possible explanation for this difference may be training intensity. However, we did not investigate the training intensity, but there was no gender difference in the amount of training during the past twelve months.

Female compared to male basketball or soccer players have shown increased risk for traumatic ankle injury (Hosea et al., 2000; Elias, 2001). Among our soccer players females had slightly more acute ankle injuries than males. Moreover, women had more overuse injuries in the ankle and in the wrist than men. While especially ankle injuries are common in both genders, effective methods of preventing sports injuries, such as use of insoles, external joint supports and multi-intervention training programs, have been proposed to prevent injuries (Aaltonen et al., 2007).

Women have been reported to have more knee injuries than men, especially ACL injuries (Arendt and Dick, 1995; de Loes et al., 2000; Dugan, 2005). Female soccer players at the time of injury have been found to be younger than male players (Bjordal et al., 1997). During the present one-year follow-up time only one male soccer player suffered from an ACL injury, but no age difference was found between the female soccer players who had ACL injury (22.3 yr) and those who did not (21.0 yr, p = 0.53). Overall, we found similar numbers of knee injuries between men and women in all four sports. Haapasalo et al. (2007) also found no gender differences in overall knee injury risk, except in endurance sports. When acute and overuse injuries in the ankle and knee were combined, female soccer players had more such injuries than male players, as has been found in earlier studies both for the ankle (Hosea et al., 2000; Elias, 2001) and for the knee (Arendt and Dick, 1995; de Loes et al., 2000; Dugan, 2005) separately. Such injuries may also cause long absence time from training and competition. However, in our study there was no difference between the sexes in time-loss from acute or overuse injury (data not shown). Injury severity is described in more details in our previous article (Ristolainen et al., in press, 2009).

Female sex has been found to be a risk factor for stress fractures in the military population (Mattila et al., 2007), but less so in athletes (Snyder et al., 2006). Iwamoto and Takeda (2003) concluded in their review that male athletes tend to have more stress fractures than women. The findings are inconsistent as Bennell et al. (1996a, 1996b) found an association between menstrual disturbances and stress fractures among runners, but Sandelin et al. (1980) found no association when studying cross-country skiers. There was 9.0% of stress fractures in female and 8.8% in male athletes. Nearly 50 % of female's stress fractures occurred to those female athletes with menstrual irregularities. So, the statistically non-significant association between menstrual irregularities and stress fractures may be due to low statistical power (type two error).

Approximately one out of every fourth female athletes report having a menstrual irregularity (Nichols et al., 2006; Torstveit and Sundgot-Borgen, 2005), and these have been more common in long-distance runners, ballet dancers and gymnasts than in swimmers (Nichols et al., 2006, Torstveit and Sundgot-Borgen, 2005). Our long-distance runners also had significantly more menstrual irregularities than soccer players and swimmers. However, we did not find any association between stress fractures and menstrual irregularities. After adjustment for exposure hours we found no association between menstrual irregularities and in the number of injuries.

In our study the average competition time between sports was fairly different (in particular between swimming and soccer playing). However, there were no difference between the sexes in the acute injury occurred in the competition within all athletes or within different sport.

We studied gender differences in four different sports, and the injury risk was counted per 1000 exposure hours. It should be noted that these sports types differed from each other in loading characteristics and that there was only one contact sport. This can be considered both a strength and a limitation in our study, as our results indicate that gender differences are independent of type of sport. However, the low number of injuries limited some sport-specific injury comparations. We sent the questionnaire to the participants immediately after the competition season, and in each sport the response rate was similar. The limitations of this study include the use of self-reported questionnaire. However, the questionnaire data were validated and reliability-tested against the interview data, and were shown to be accurate (Eloranta and Tittonen, 2006; Karhula and Pakkanen, 2005). Retrospective data collection is a limitation in our study. Also, the validation method we used does not exactly reveal the accuracy and coverage of the reported injuries, but was more adequate for measuring the reproducibility/repeatability of the data collection. Comparability between different sports should not be a problem in our study as the method applied was the same for all four sports studied. In addition, the athletes in each sport were on the top-ranking list in their sports, and for this reason were to some extent comparable despite their different sport events.

Conclusion

The overall gender-related risk for acute and overuse injuries in top-level athletes between the sexes was small. However, we found some gender differences in the specific anatomical locations of injuries as well as in specific injuries in sports. Some of these differences seem to be explained by the differences in the amount of training.

Acknowledgments

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Key points

- Only a few sport injury studies have compared injury rates between the sexes
- Overall gender-related risk for acute and overuse injuries in top-level athletes between the sexes was small
- Some gender differences in the specific anatomical locations of injuries as well as in specific injuries in sports were found
- Some of these differences seem to be explained by the differences in the amount of training

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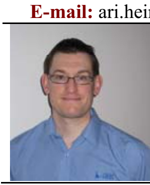

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III

Training-related risk factors in the etiology of overuse injuries in endurance sports (manuscript)

by

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Submitted

III

Training-related risk factors in the etiology of overuse injuries in endurance sports

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ABSTRACT

Aim. The purpose of this study was to clarify training-related risk factors for overuse injuries.
Methods and materials. This was twelve-month retrospective study which was done by self-reported postal questionnaire. The study group consisted of 446 men and women top-level Finnish athletes representing three different endurance sports (cross-country skiing, swimming, long-distance running) between the ages of 15 - 35.
Risk Factors and Outcome Measurement(s). Self-reported anthropometric and training-related variables (such as starting age of training, years of active training, hours trained yearly, competition hours and weekly resting days) and occurrence of overuse injuries.
Results. Athletes with less than 2 weekly resting days during the training season had 5.2-fold risk (95% confidence intervals [CI] 1.89-14.06, P=0.001) for an overuse injury, and athletes who trained more than 700 hours during a year had 2.1-fold risk (95% CI 1.21-3.61, P=0.008) for an overuse injury compared to the others. Athletes with a tendon injury were on average two years older than athletes without such an injury (P<0.001).
Conclusion. We found that low number of recovery days and a high amount of training are training-related risk factors for overuse injuries in top-level endurance athletes. The higher number of tendon overuse injuries in older than younger athletes may indicate that age-related degeneration plays an important role in the etiology of tendon injuries. These findings should be taken into account when planning exercise programs for endurance athletes.

KEY WORDS: Overuse injury - Risk factor - Cross-country skiing – Swimming - Long-distance running

INTRODUCTION

Overuse injuries are common among endurance athletes. Overuse injuries have serious consequences in terms of costs and training reduction. Injury prevention is necessary and we need to know the cause of injury more specifically before planning preventive methods. Earlier studies have shown that overuse injury occurrence is anatomically strictly linked to the specific loading patterns of each sport.[1] Most studies investigating risk factors for overuse injury have focused on running injuries.[2, 3] Studies have also focused specifically on lower extremity injuries,[4-6] and on injuries related to cross-country skiing [7, 8] and swimming.[9, 10]

Injury risk factors can be classified to be either extrinsic, environmental risk factors or intrinsic, subject-related risk factors.[11, 12] Training errors, such as not allowing enough resting time and fatigue, are one of the most important extrinsic risk factors for an athlete,[13] and they are rather easily modifiable. Environmental conditions, like terrain, climate and equipments, play also a major role in the outcome of an injury.[13] Subject-related risk factors for injuries include gender,[14] increased age,[15] and previous injury.[11, 15, 16] In van Mechelen et al. study[11] exposure time and previous injury was reported to be more important predictors of sports injuries than psychological, psychosocial, physiological, and anthropometrical factors. Menstrual status among female athletes has also been shown to be risk factor for an overuse injury.[17] In addition, there may be many types of interactions between intrinsic and extrinsic risk factors, such as older athletes may be at higher or lower risk for specific injuries than younger athletes during standard training programs. These interactions have not been studied widely.

An overuse injury usually occurs gradually due overload or repetitive micro trauma, but can also be a result of inadequate recovery time between applied forces.[2, 6, 18] Tendon overuse injuries in particular are common in endurance athletes.[18] Different etiological factors and underlying mechanisms may lead to tendon degeneration, thereby reducing the tensile strength of the tendon.[19] However, the etiology of degenerative overuse tendinopathies is unknown.[20] Structural damage may require a longer healing period than has earlier been thought.[18] Also mechanical loading can stimulate or delay the repair process.[20] Studies on risk factors for muscle injuries have mainly focused on hamstring injuries[21, 22] and soccer players.[21, 22] It has been suggested that muscle injury incidence decreases with restoration of normal strength or by increasing flexibility,[21, 23] but evidence of the effectiveness of these interventions remains insufficient.[24] In addition, poor hamstring flexibility, greater body weight, greater weekly mileage, and greater muscular strength were related to larger joint loading, especially in the knee.[25] Reducing these risk factors may also decrease the risk of joint injury. However, musculoskeletal injuries are usually result of the interaction of multiple risk factors.[13]

The volume of exercise engaged in by top-level athletes (including frequency, intensity and duration of training sessions) can be very demanding. Thus training-related factors may play an important role in the etiology of overuse injuries. Little appears to be known about the risk factors for overuse injuries related to skiing and swimming.[8-10, 26] The aim of our study was to analyze overall training-related risk factors for muscle, tendon and joint overuse injuries in cross-country skiing, in swimming, and in long-distance running. Despite known limitations [27-29] of the method, we used retrospective questionnaires to document the injuries, as it is difficult to organize standardized nation-wide detailed injury data collections covering various individual sports in other way as there is no uniform injury treatment organization.

MATERIALS AND METHODS

Participants

Data were collected by a retrospective twelve-month questionnaire which was sent to Finnish top-level female and male endurance athletes (15–35 years old). The athletes (n=833) were cross-country skiers (n=300), swimmers (n=268) and long-distance runners (n=265). Top-level athletes were defined as the best-ranked Finnish athletes in the three above-mentioned sports in the 2005 season. The best Finnish male and female skiers were identified according to the ranking list of the Finnish Ski Association. The best swimmers, according to the FINA points system in 2005, over different swimming distances in a 50m pool were taken from the website of the Finnish Swimming Association. All the female and male runners whose personal record in 2005 was better than the C level in one of the running distances from 1500m to the marathon were included in the study. In the individual sports, athletes were top-ranking at the end of the previous season. In cross-country skiing 11 athletes and in long-distance running 3 athletes over 35 years old were excluded. We excluded athletes over age 35 because they may already be subject to a degenerative process and this may influence their injury profile. One hundred and sixty-nine skiers, 166 swimmers and 163 runners returned the questionnaire (59.8%, 498/833). Of the responded athletes, 446 fulfilled the questionnaire (53.4%, 446/833).

The term overuse injury was defined as follows: an injury causes pain during exercise loading without any noticeable external cause of injury. The injury gradually causes worsening pain during or after exercise. The pain becomes worse when loading is continued and may lead to complete cessation of exercise, or needs a physician's care. The term acute injury was defined as follows: an acute sports injury occurs suddenly or accidentally, interrupting the exercise or the competition of the athlete or causing an identifiable trauma. One criterion of an acute injury is that it keeps the athlete away from at least one training session, or competition, or needs a physician's care. All overuse and acute injuries were recorded separately but acute injuries were excluded from this study.[1] Therefore in this article the term "injury" refers to "overuse injury". The specific incidence of acute and overuse injuries, their anatomical location, and sex differences have been reported earlier.[1, 30] The total number of exposure hours per year (training and competition hours) was calculated on the basis of six questions (Table I). Female respondents were also asked to state status of menstrual cycle. The questions the athletes were asked concerning overuse injury risk factors are presented in Table I.

The retrospective questionnaire was validated and reliability-tested against the interview data, and was found to be accurate.(31, 32) The reliability of the event and training information was good or excellent (ICC=0.81 – 0.95, P<0.001). Questions which were not repeatable or unable to understand correctly were omitted from the final questionnaire. The study protocol was approved by the ethics committee of the University of Jyväskylä.

TABLE I. - *Questions used in the study.*

Anthropometrics and sport

- Sex
- Birthday
- Age
- Height
- Weight
- Sport

Menstrual cycle

- Have you begun menstruation? 1. no 2. yes, at what age____?
    a) Menstruation is regular, cycle is about_____ days
    b) Menstruation is irregular, about _____times per year, the longest period about ____days, the shortest period about ___days
    c) Menstruation has begun, but finished ____ / ____ (month / year)

Overuse injury

- Have you had an overuse injury during past 12 months? (yes/no)
- If yes, how many overuse injuries have you had? (number)
- State location of overuse injury/injuries (28 different anatomical site was mentioned)
- In which tissue did the overuse injury/injuries occur? (muscle, tendon, bone, joint, ligament, nerve tissue)

Training

- In what age did you start training for your main sport? ______ years of age
- How many years have you been in active training in your main sport (at least 2 times / week)? _______ years
- How long is your annual mean training season (the part of the year when you train regularly but don´t compete regularly in your main sport)? _______months *
- How long is your average training time per week, including all your sports, during the training season ? ____hours/week,____times/week *
- How long is your annual mean competition season? Count together all the different competition seasons, if more than one seasons._______months *
- How long is your average training time per week, including all your sports, during the competition season? ____hours/week, _____times/week*
- On average, how many competitions have you participated in on average during the past twelve months? _____competitions/year
- On average, how long did a competition last? Competition time _____minutes
- How many training camp days in total have you had during the past twelve months? ________days
- How many whole resting days per week do you have on average in the training season? ______resting days/week
- How many resting days per week do you have on average in the competition season? ______resting days/week
- How many kilometers have you skied, swum and run during past 12 months?

*The total number of exposure hours per year (training and competition hours) was calculated on the basis of these questions

Statistical Analyses
The statistical analyses were performed with SPSS (Version 15.0; Inc., Chicago, IL.) Frequencies, proportions, mean and standard deviations (SD) were used as descriptive statistics. Pearson chi-square was applied to calculate statistical differences in the distributions between the different sports. *t* tests were applied to compare skiing, swimming and running kilometres between injured and non-injured athletes and also to compare the age of first menses between injured and non-injured female athletes. Univariate analysis of variance, with sex and sport as covariates in the between-sports analysis and sex as a covariate in the within-sport analyses, was used to compare athletes without and with tendon, joint, muscle and all other overuse injuries. The level of significance was set at $P<0.05$. The results of the analyses of the risk factors for injuries were adjusted for sex and sport (covariate-adjusted) except for the risk factors within each sport, which were as adjusted only by sex, and menstrual status, which was adjusted only by sport. We used logistic regression models to analyze the association between covariates and injuries. Sex and sport were used as covariates in all the logistic regression models. When investigating the risk factors for injuries between the different sports, we used swimming as a reference sport in all the logistic regression models except for injuries to the upper extremities, where the corresponding reference sport was running. The associations were expressed using odds ratios (OR) and their 95% confidence intervals (CI). P values were below 0.05.

RESULTS

The questionnaire was returned by 446 top-level athletes (149 cross-country skiers, 154 swimmers and 143 long-distance runners). The question "Have you had an overuse injury during the past twelve months" was answered by 441 athletes. Two hundred and thirty-eight athletes reported at least one injury (54%, 238/441), and the total number of injuries was 352. Anthropometrics and training information are shown in Table II.

All overuse injuries

There were 50% of the studied cross-country skiers, 51% of the swimmers and 59% of the long-distance runners who have had at least one overuse injury during past year (Table II). Skiers' overuse injury incidence (injuries to 1000 exposure hours) was 1.35, in swimmers it was 1.48 and in runners 1.67. Specific overuse injury incidence by different anatomical locations is seen in Table III.

The mean age of the athletes with at least one injury compared to those with no injury during the past twelve months was higher after adjustment for sex and sport (P=0.01) (Table IV). This was especially seen in long-distance runners (sex-adjusted means 25.3 y vs 22.9 y, P=0.007).

The covariate adjusted mean of exposure hours showed a trend in the athletes with an injury compared to those with no injury (P=0.12) (Table IV). The average number of training camp days was significantly higher in the athletes who had an injury than in those without an injury (P=0.04) (Table IV). The athletes with an overuse injury had on average fewer resting days weekly during the training season compared to those with no injury (P=0.006) (Table IV). First menses had, on average, earlier in the athletes with an injury than in those without (P=0.03) (Table IV).

TABLE II. - *Characteristics of the study group.*

	Cross-country skiing N=149 Female N=87 Male N=62	***Swimming*** N=154 Female N=83 Male N=71	***Long-distance running*** N=143 Female N=76 Male N=67	***All athletes*** N=446 [*] Female N=246 Male N=200
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Numbers of athletes with at least one overuse injury (n/%)	74±49.7	79±51.3	85±59.4	238±53.4
Number of overuse injuries (n)	110	117	125	352
Age (yr)	22.7±4.4	18.6±2.9 [a]	24.3±5.3	21.8±4.9
Height (cm)	173.3±8.2	176.4±9.1 [b]	172.9±8.8	174.2±8.9
Weight (kg)	65.4±9.3	69.8±11.3 [c]	59.8±8.9	65.1±10.7
Body Mass Index (kg/m²)	21.7±1.6	22.3±2.1 [d]	19.9±1.5	21.3±2.0
Menstrual cycle begun (age)	13.8±1.5	12.9±1.1 [e]	13.9±1.6	13.5±1.5
Starting training (age)	7.6±3.1	8.0±2.2 [f]	12.2±4.8	9.2±4.1
Active training (years)	11.6±4.5	9.9±3.1 [g]	10.4±5.1	10.6±4.4
Exposure hours during year (h/yr)	564±155	767±326 [h]	554±257	628±271
Competitions during year (n)	26.8±8.2	12.2±6.0 [i]	18.9±11.6	19.2±10.7
Camping days during year (d)	38.4±27.2	13.2±13.3 [j]	16.0±22.3	22.4±24.4
Resting days in a week during training season (d/wk)	0.9±0.5	1.1±0.5 [k]	0.7±0.6	0.9±0.5
Resting days in a week during competition season (d/wk)	1.2±0.5	1.3±0.7 [l]	1.1±0.7	1.2±0.7

[*] All athletes who responded to the questionnaire.
[a] Swimmers were younger than cross-country skiers (P<0 .001) and long-distance runners (P<0.001), and skiers were younger than runners (P<0.05)
[b] Swimmers were taller than skiers (P=0.002) and runners (P<0.05).
[c] Swimmers weight was greater than in skiers (P<0.001) and runners (P<0.001), skiers weight was greater than in runners (P<0.001).
[d] Swimmers BMI was greater than in skiers (P<0.05) and runners (P<0.001), and skiers BMI was greater than in runners (P<0.001).
[e] Swimmers menstrual cycle begun earlier than in skiers (P<0.001) and in runners (P<0.001).
[f] Swimmers were started their sport earlier than runners (P<0.001).
[g] Swimmers had less active training years than skiers (P<0.001).
[h] Swimmers had greater exposure hours during year than in skiers (P<0.001) and in runners (P<0.001).
[i] Swimmers had less competitions during year than in skiers (P<0.001) and in runners (P<0.001).
[j] Swimmers had less camping days during year than in skiers (P<0.001) and runners had less camping days than in skiers (P<0.001).
[k] Swimmers had longer resting days during training season than in skiers (P<0.05) and in runners (P<0001). Skiers had longer resting days in a week than in runners (P<0.05).
[l] Swimmers had longer resting days during competition season than in runners (P<0.05).

Sport, sex, age, training camp days during the year, and number of resting days weekly during the training season were entered into a logistic regression analysis to identify independent predictors for injuries. According to our multivariate model, age increased the risk for sustaining an injury (Odds Ratio [OR] 1.06/year; 95% Confidence Interval [CI] 1.008-1.108, P=0.02) while a higher number of weekly resting days in training season had a preventive effect (OR 0.66/day, 95% CI 0.44-0.995, P=0.05). From these three endurance sports only injured swimmers had swum significantly more than non-injured swimmers during past twelve months (1612 km vs 1380 km, P=0.04). Differences in skiing kilometres between injured and non-injured skiers (3065 km vs 2912 km, P=0.43) and in running kilometers between injured and non-injured runners (3357 km vs 3020 km, P=0.27) were non-significant. First menses had, on average, occurred earlier in athletes with at least one injury compared with athletes with no injury (Table V). The training-related risk factors for injuries are shown in more detail in Table V.

From a clinical point of view we also categorised the significant training-related risk and supportive factors for an injury. Injury risk was five times higher in athletes with less than two resting days weekly during the training season compared to athletes with more than two resting days weekly (OR 5.16; 95% CI 1.89-14.06, P=0.001). Higher risk was also seen in athletes with over 700 exposure hours during the year than athletes less than 700 exposure hours (OR = 2.10, 95% CI = 1.21, 3.61, P=0.008). In athletes with more than 12 active training years injury risk was higher than athletes with less than 12 active training years (OR 1.67; 95% CI 1.11-2.52, P=0.01).

Tendon injuries

A total of 102 tendon injuries was reported by 92 athletes (20.9%, 92/441). The most common anatomical sites for tendon injury were the Achilles tendon (22.5%, 23/102), knee region (20.6%, 21/102), and shoulder region (14.7%, 15/102). The risk for tendon injury was 2.3-fold (95% CI 1.26-4.04, P=0.006) in long-distance runners compared to swimmers. One-fifth of the cross-country skiers had at least one tendon injury.

The covariate-adjusted mean age of athletes with at least one tendon injury was higher compared to those without such an injury (P<0.001) (Table IV). Exposure hours during the past year were not associated with tendon injuries (Table IV), but the athletes with at least one tendon injury compared to those without a tendon injury had on average fewer resting days weekly during the training season (P=0.03) (Table IV). The athletes with a tendon injury had started their sporting career one year later (P=0.05), but reported more active training years (P=0.003) than those without such an injury (Table IV). Number of kilometres run during the past year was not associated with having or not having a tendon injury in the runners (3331 km vs 3172 km, P=0.61).

To further analyze the predictors for tendon injuries, sport, sex, age, start training age, and number of weekly resting days in the training season were entered into a logistic regression analysis. The only predictor of risk for an injury was age (OR 1.08/year; 95% CI 1.02-1.14, P=0.005). The training-related risk factors for tendon injuries are shown in Table V.

TABLE III. - *Specific information of injuries (n/%) and injury incidence per 1000 exposure hours in different sports.*

	Cross-country skiers		Swimmers		Long-distance runners	
	Injuries	Injury incidence	Injuries	Injury incidence	Injuries	Injury incidence
Anatomical site	N (%)	N / 1000 *	N (%)	N / 1000 *	N (%)	N / 1000 *
Neck region	2 (1.9)	0.05	2 (1.7)	0.07	0 (0.0)	0.0
Upper arm, shoulder	2 (1.9)	0.06	61 (52.1)	1.82 [a]	1 (0.8)	0.03
Forearm, elbow, palm, wrist, fingers	8 (7.4)	0.21 [b]	7 (6.0)	0.18	1 (0.8)	0.0
Back	18 (16.7)	0.42 [c]	17 (14.5)	0.23	7 (5.5)	0.18
Hip, groin, buttock, pelvis	8 (7.4)	0.19 [d]	2 (1.7)	0.03	15 (11.7)	0.24 [d]
Thigh	5 (4.6)	0.13	1 (0.9)	0.02	10 (7.8)	0.19 [e]
Knee	21 (19.4)	0.55	19 (16.2)	0.43	21 (16.4)	0.42
Calf and shin	16 (14.8)	0.34 [f]	1 (0.9)	0.01	15 (11.7)	0.34 [f]
Ankle	4 (3.7)	0.11	4 (3.4)	0.05	6 (4.7)	0.12
Foot (toes, sole, heel, Achilles)	24 (22.2)	0.59 [g]	3 (2.6)	0.02 [g]	52 (40.6)	1.19 [g]

* Values are number of overuse injuries per 1000 exposure hours in different sport. P -values are based on t test.

a Injury incidence in the upper arm and shoulder were higher in swimmers than in skiers ($P<0.05$) and in runners ($P<0.05$).

b Injury incidence in the forearm, elbow, palm, wrist and fingers was higher in skiers than in runners ($P=0.05$).

c Injury incidence in the back was higher in skiers than in runners ($P<0.05$).

[d] Injury incidence in the hip, groin, buttock and pelvis was higher in runners ($P<0.05$) and skiers ($P<0.05$) than in swimmers.

[e] Injury incidence in the thigh was higher in runners than in swimmers ($P<0.05$).

[f] Injury incidence in the calf and shin was higher in skiers ($P<0.001$) and in runners ($P<0.05$) than in swimmers.

[g] Injury incidence in the foot was higher in runners ($P<0.001$) and in skiers ($P<0.001$) than in swimmers, and higher in runners than in skiers ($P<0.05$).

TABLE IV. - *Covariate-adjusted variables between athletes without and with tendon, joint, muscle and all overuse injuries.*

	Overuse type							
	Tendon Sex and sport adjusted		Muscle Sex and sport adjusted		Joint Sex and sport adjusted		All overuse injury Sex and sport adjusted	
	no injury N=349 Mean	≥ 1 injury N=92 Mean	no injury N=366 Mean	≥ 1 injury N=75 Mean	no injury N=391 Mean	≥ 1 injury N=50 Mean	no injury N=203 Mean	≥ 1 injury N=238 Mean
Age (yr)	21.4	23.5**	21.9	21.6	21.8	22.4	21.3	22.4*
Height (cm)	174.4	173.5	174.0	175.3	174.2	174.6	174.4	174.1
Weight (kg)	65.4	63.7	64.7	66.6*	64.8	66.9	65.5	64.7
BMI (kg/cm^2)	21.4	21.1	21.2	21.5	21.2	21.8*	21.4	21.2
Menstrual cycle starting (age) [a, b]	13.5	13.4	13.5	13.4	13.5	13.4	13.7	13.3*
Starting training (age)	9.1	10.0*	9.3	9.2	9.2	9.7	8.9	9.5
Active training (years)	10.3	11.7*	10.7	10.3	10.5	11.2	10.2	10.9
Exposure hours during year (h/yr)	624	639	624	645	618	700*	604	646
Competitions during year (n)	19.1	20.2	19.3	19.3	19.7	16.3*	19.2	19.4
Training camp days during year (n)	22.1	24.1	22.2	23.8	22.4	23.1	20.1	24.5*
Resting days per week during training season (d/wk)	0.9	0.8*	0.9	0.9	0.9	0.9	1.0	0.9*
Resting days per week during competition season (d/wk)	1.2	1.2	1.2	1.2	1.2	1.1	1.3	1.1*

[a] Only sport-event adjusted. There were 235 from 246 female athletes who reported their menstrual cycle starting age.

[b] No tendon injury N=184, one or more tendon injuries N=51

[b] No joint injury N= 209, one or more joint injury N=26

[b] No muscle injury N=195, one or more muscle injuries N=40

[b] No overuse injury N=114, one or more overuse injuries N=121

*P<0.05

**P<0.001

TABLE V. - *Logistic regression analysis without and with tendon, muscle, joint and all overuse injuries.*[a]

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	Tendon injury N=92		Muscle injury N=75		Joint injury N=50		All overuse injury N=238	
	Sex and sport adjusted							
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Age (yr)	1.07*	(1.02-1.13)	0.99	(0.93-1.05)	1.08*	(1.008-1.16)	1.05*	(1.002-1.098)
Height (cm)	0.99	(0.95-1.03)	1.03	(0.99-1.08)	0.99	(0.95-1.05)	0.99	(0.96-1.03)
Weight (kg)	0.99	(0.96-1.03)	1.04	(0.99-1.08)	1.02	(0.97-1.06)	0.99	(0.97-1.03)
BMI (kg/cm²)	1.02	(0.87-1.20)	1.10	(0.93-1.30)	1.11	(0.92-1.34)	1.004	(0.88-1.14)
Menstrual cycle starting (age) [b]	0.88	(0.70-1.10)	0.92	(0.72-1.18)	0.98	(0.72-1.35)	0.81*	(0.67-0.98)
Starting training (age)	1.02	(0.96-1.09)	1.01	(0.94-1.08)	1.11*	(1.02-1.20)	1.02	(0.97-1.08)
Active training (yr)	1.08*	(1.02-1.14)	0.98	(0.92-1.04)	1.05)	(0.97-1.13	1.04	(0.99-1.09)
Exposure hours during year (h/yr)	1.001	(1.000-1.002)	1.000	(0.99-1.001)	1.001	(1.000-1.002)	1.001*	(1.000-1.002)
Competitions during year (n)	1.01	(0.99-1.04)	1.001	(0.97-1.03)	0.95*	(0.90-0.99)	1.002	(0.98-1.02)
Training camp days during year (n)	1.01	(0.996-1.016)	1.003	(0.99-1.01)	1.000	(0.99-1.02)	1.011*	(1.002-1.021)
Resting days per week during training season (d/wk)	0.66	(0.40-1.09)	0.73	(0.42-1.26)	0.78	(0.40-1.50)	0.61*	(0.41-0.91)
Resting days per week during competition season (d/wk)	0.96	(0.67-1.38)	0.91	(0.61-1.34)	0.76	(0.47-1.23)	0.77	(0.57-1.03)

OR: Odds ratio, 95% CI: 95% Confidence Internal

a Adjusted for sex and sport, from logistic regression analysis, OR is per unit increase in each risk factor.

b Only sport adjusted

* P<0.05

Joint injuries

Fifty-nine joint injuries (12 running, 13 skiing and 34 swimming injuries) occurred in 50 athletes. In half of the runners (6/12) and over forty percent (6/13) of the skiers the joint injuries were sustained to the knee. Nearly sixty percent (20/34) of the joint injuries in the swimmers were in the shoulder region. The number of competitions was on average lower in the athletes with a joint injury than in those without a joint injury (P=0.01) (Table IV). The mean number of kilometres swum was higher in swimmers with at least one joint injury compared to swimmers without such an injury (1750 km vs 1437 km, P=0.03). There were no differences between number of kilometers of skiing or running kilometers and joint injuries.

Sport, sex, age, BMI, exposure hours during the past year, and number of competitions were entered into a logistic regression analysis to identify independent predictors for joint injuries. A lower number of competitions during the past year was a preventive factor for a joint injury (OR 0.95/unit decrease; 95% CI 0.91-0.0995, P=0.03).

Muscle injuries

Eighty-nine muscle injuries occurred in 75 athletes (17.0%, 75/441). The most common anatomical sites for a muscle injury were shin and calf combined (24.7%, 22/89), low back (20.2%, 18/89) and the shoulder region (20.2%, 18/89). Over fifty percent (18/31) of swimmers' muscle injuries were reported in the shoulder region, whereas among the runners (39.3%, 11/28) and the skiers (33.3%, 10/30) shin and calf injuries were the most common anatomical site of the overuse injury. The athletes with a muscle injury were slightly heavier than the athletes without a muscle injury (covariate-adjusted mean 66.6 kg vs 64.7 kg, P=0.05) (Table IV).

Sex, sport, age and weight were entered into a logistic regression analysis to identify the risk factors for a muscle injury. The only risk factor that emerged was higher weight (OR 1.04/kg increase; 95% CI 1.001-1.082, P=0.04).

DISCUSSION

Our purpose was to study the training-related risk factors for tendon, muscle and joint overuse injuries as well as for all overuse injuries in top-level endurance athletes. In general, older athletes were at a higher risk for injury; this was especially evident among the long-distance runners and in respect of tendon injuries. The athletes with less than two resting days weekly during the training season had an over five-fold risk for an injury. The athletes with more than 700 hours exposure during the year had a two-fold risk for an injury.

The role of age as a risk factor for injuries remains controversial. Some studies have shown that in runners injury risk is independent of age.[7, 33] Sandelin et al.[8] found that male cross-country skiers under 30 years had more injuries than older ones, and Marti et al.[33] concluded that with increasing age the incidence of running injury decreased. Engebretsen et al.[34] in turn found that injured male and female winter sports athletes did not differ in age from their non-injured counterparts. In our study, regularly competing athletes with an injury were on average one year older than those without such an injury.

Earlier studies[7, 33] have suggested that running volume is a risk factor for injuries, although conflicting results exist.[2, 35] Hreljac et al.[4] also found no differences between distance run weekly between those who had never sustained an overuse lower limb injury attributed to running and those that had sustained at least one overuse injury attributed to running. Similarly, we found no association between injuries and number of kilometres run weekly, but a low number of weekly rest days and high number of training camp days were associated with higher risk for overuse injury. Van Mechelen et al.[11] in their study of the general population found that high exposure time was a risk factor for overall injury. Among our athletes, those with a high number of annual exposure hours were at increased risk for injury. Because there were a quite few number of athletes in the different sports with over 700 hours/year of training and because the annual number of exposure hours varied between the different sports, we counted all three sports together. Furthermore, a trend emerged that overuse injuries were common in athletes with long running experience. In an earlier study, runners with more than ten years experience had an increased risk for Achilles tendinopathy. [36] However, Plisky et al.[37] found no association between running experience and medial tibial stress syndrome. These conflicting results may be explained by differences in the overuse injury, the populations studied, and the study design. The so called "healthy exerciser bias" (those who are not injured score more training hours) may also explain the differences in results between studies.

Among swimmers and skiers overuse musculoskeletal injuries can also result from training other than swimming or skiing, including weight lifting, plyometrics, and running.[1, 38] The return to training after an injury must follow a logical, gradual progression to prevent recurrence. A gradual return over time will have greater benefits on performance in the long term than doing too much, too soon.[38] Training without resting may have a negative influence on overuse injuries. Vetter & Symonds [39] found that there does not seem to be a real ''off season'' as athletes train for almost 12 months a year. They suggested that periodization and rest are extremely important to help avoid overreaching and overtraining leading to excessive physical exhaustion and injury. Jones [40] reported that upper-extremity overuse injuries such as stress fractures have also become more frequent among athletes, and that a majority of these fractures are caused by overuse and fatigue of the surrounding musculature. We found also in our study that weekly resting time, along with appropriate training and conditioning, is important to athletes to prevent overuse injuries

Because tendon, joint and muscle overuse injuries were the most common types in our athletes, we concentrated on these injuries. A high number of active training years were associated with tendon injuries, and our athletes with tendon injuries were also older than those without such injuries. Only 16% of the athletes under age 20, but 39% of the athletes over age 30 had suffered from a tendon injury. Kujala et al.[41] also reported that tendon problems are common among former elite older endurance athletes. Age-related degeneration seems to play an important role in the etiology of tendon injuries.[41] The majority of sports-related tendinopathies develop as a result of either excessive quantity or poor quality of movement, or both. Repetitive loading of tendon within the physiologic range leads to cumulative microtrauma, which may require days or weeks to fully self-repair.[42] Tendon injuries were especially common among the present long-distance runners with, typically, a short weekly resting time from training. The runners with tendon injuries had on average more exposure hours per year than those without such an injury. Our findings support the suggestion, that overuse injuries can partly be explained by excessive training without enough resting time. An average of two resting days per week clearly reduced the risk of injury, and there was a statistically non-significant trend that those athletes who had on average one day of rest per week had a 15% lower risk of injuries compared to those with fewer resting days. Sein et al.[43] reported that the number of hours swum/week and weekly mileage both correlated significantly with supraspinatus tendinopathy in elite swimmers. In our study a correlation was found in swimmers between annual number of kilometers swum and a joint injury. However, no correlations between swimmers or skiers with a tendon injury and annual swimming or skiing kilometers (results not shown) were found. To avoid injuries, proper resting time is important for all athletes, and may be especially important for older athletes with a long training history.

Overall, we did not found many risk factors for joint injuries in endurance athletes. Athletes with a joint injury reported on average to having fewer competitions during the year than the others. This may, however, be partly explained by long absence (over 3 weeks) from competitions in the athletes with a severe joint injury (results are not shown). Among swimmers high exposure time was associated with joint injuries.

Muscle injuries have been reported to be common among cross-country skiers.[8] This also emerged in our study. Every third cross-country skier in our sample had a muscle injury in the low back, and in accordance with earlier findings [44, 45] these injuries were more common when using the classic than the skating technique. In classic skiing the spine is loaded by repetitive movements from extension to deep flexion and also by repetitive rotation, while in the skating technique the spine is held more stable and in a vertical position. [44, 45] Repetitive movements in the back may contribute low back injuries and pain.

Recurrent compartment syndrome occurs when the pressure in a muscular compartment is intermittently elevated during high levels of activity in that group of muscles. The deep posterior compartment in the lower leg is the most commonly affected and this may cause medial tibial pain.[46] This is common especially among runners.[37] In our study, in every fourth athlete with a muscle overuse injury, especially among skiers and runners, the injury was located in the shin or calf. In the study by Moen et al.[47] a higher body mass index was associated with longer duration to full recovery from medial tibial stress syndrome, and Plisky et al.[37] also reported that a higher body mass index is a risk factor for such a syndrome. In the present study we did not examine the recovery time from injury in relation to specific types of injury. However, we found that weight was a slight risk factor for all muscle injuries. We did not find any other training-related risk factors for muscle injuries.

This study has some limitations. Our questionnaire was rather long that might have an influence on the response rate. Further, we used retrospective self-reports to document injuries, since our large nation-wide survey covered various individual sports. It has been shown that retrospective study has some restriction, such as recall bias:[48] a memory decay, which means the loss of information due to failure to recall the event, and the telescoping effect, which is the tendency to remember events in the past as if they occurred closer to the present than they actually did. Junge & Dvorak [28] found that the one-year incidence of injuries reported retrospectively was significantly lower than that documented on the basis of weekly follow-up examinations. Braham et al.[27] suggest that data should be collected on site and not rely on athletes recall. However, Gabbe et al.[49] found that there can be both overreporting and underreporting in a self-reporting survey. Walter & Hart[29] reported that retrospective surveys are less likely to provide accurate incidence data because they rely on athletes' responses and on diagnoses that lack verification by a physician. Therefore, these limitations should be kept in mind when interpreting the results. On the contrary, Valuri et al.[50] noted that self-reported data agreement was highest for details such as the body part injured, but did not appear to be an accurate source of information concerning the injury severity. In our study the severity of the injury was defined according to the time loss from training and competition which is easier to report by the athletes due to fact that elite athletes also usually keep a training diary, which can be expected to improve the accuracy of the data reported in questionnaires. In addition, our athletes tend to have close relations of co-operation with physicians regarding their medical problems, and athletes also know about more their injuries than other laymen. In a retrospective study cause and effect may be difficult to determine. It may be possible that some risk factors are a result rather than a cause of injuries. When using self-reports the exact diagnosis of injury is difficult. According to the study by Gabbe et al.[49] recall accuracy declines as the level of detail requested increases. It is for this reason that we did not analyze diagnosis and other specific injury details to avoid false results. The present differentiation of tendon, muscle and joint injuries are based on self-diagnosis, which may decrease the accuracy of the report regarding the type of injury.

CONCLUSIONS

Overuse injuries were common in our top-level endurance athletes. Older athletes and athletes with less weekly resting time during the training season more commonly reported at least one injury. Risk for tendon injury increased with age. Excessive training and inadequate rest may lead to overuse injuries. These findings should be taken into account when planning exercise programs for endurance athletes.

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IV

Sport injuries as the main cause of sport career termination among Finnish top-level athletes

by

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ORIGINAL ARTICLE

Sport injuries as the main cause of sport career termination among Finnish top-level athletes

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Abstract

Injuries are common among athletes, and are sometimes so severe that they affect an athlete's career in sport. As studies on sport career termination are few, we conducted a study to investigate the role of injuries as a reason for ending a sport career. The study group consisted of 574 male and female top-level cross-country skiers, swimmers, long-distance runners and soccer players who responded to a retrospective postal questionnaire in 2006. Twenty-seven athletes (4.9%, 27/548) reported ending their sport career because of injury. A follow-up interview was conducted by telephone in 2007 ($n = 20$ volunteered to be interviewed) to confirm sport career termination and the reasons for this. Fifteen of the interviewed athletes terminated and five continued their sport on the same level as earlier. Female athletes (12/15) terminated their sport career more frequently than male athletes (3/15). Athletes who reported terminating their sport career because of injury were on average two and a half years older (24.1 years vs. 21.6 years, $P = 0.006$) than athletes who continued the sport. All the swimmers ($n = 5$) who were interviewed terminated their career because of a shoulder injury. All the soccer players who ended their career ($n = 4$) were female and had a severe knee injury, such as anterior cruciate ligament injury. Most of the athletes who terminated their sport career (70.4%, 19/27) reported that the injury caused them mild or moderate permanent disability. We found that sports injuries play a significant role in terminating a career in sport, and in some sports events injuries may commonly be the main reason for sport career termination. Injury prevention and adequate treatment and rehabilitation of injuries are thus essential to avoid the long-term consequences of severe sport injuries.

Keywords: *Athletic injury, sport career, severe injury*

Introduction

Regular physical activity is essential for optimal functioning and important for health (Kujala, 2004; Kujala, Orava, Parkkari, Kaprio, & Sarna, 2003; Nelson et al., 2007). Injuries are common among athletes and, in severe cases, can terminate an athlete's career in sport. Only a few studies have investigated the reasons for ending a sport career. Most of these studies have been quantitative and have focused on psychological factors such as self-esteem and life satisfaction (Brown, Gilbourne, & Claydon, 2009; Perna, Ahlgren, & Zaichkowsky, 1999; Thing, 2006). Some studies have focused on either male or female athletes (Drawer & Fuller, 2001; Söderman, Pietila, Alfredson, & Werner, 2002; Thing, 2006), while studies including both sexes are rare (Darrow, Collings, Yard, & Comstock, 2009). The role of injuries as a reason for ending a career in sport has been little studied. Kettunen, Kujala, Kaprio, Koskenvuo, and Sarna (2001) reported that every fifth athlete in a sample of former elite male athletes had terminated their career because of an injury, and in the study by Drawer and Fuller (2001) injuries accounted for as many as 47% of such cases. According to Vuolle (2008), nearly half of Finnish ice hockey players reported that one of the reasons for ending their career in sport was an injury. Studies on this issue have mainly concentrated on team sports like soccer (Drawer & Fuller, 2001; Söderman et al., 2002), where severe injuries,

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such as anterior cruciate ligament injuries (ACL), are more common (Söderman et al., 2002; Walden, Hagglund, Werner, & Ekstrand, 2011). Studies focusing on athletes who terminate their sport career, and the influence of injuries on this decision, are lacking. Our purpose was to investigate the role of injuries as a reason for ending a sport career among Finnish top-level athletes drawn from sports with different types of loading (cross-country skiing, swimming, long-distance running and soccer).

Methods

The target group of this retrospective injury study consisted of top-level Finnish male and female athletes (range 15–35 years) representing four different sports and loading modalities (Ristolainen et al., 2010). The athletes included cross-country skiers (repetitive loading on upper and lower extremities), swimmers (repetitive loading on upper extremities without impact loads), long-distance runners (repetitive loading on lower extremities) and soccer players (high risk for impact loads and sprains). The best Finnish male and female skiers were identified according to the ranking list of the Finnish Ski Association. The best swimmers were recruited according to the Fédération Internationale de Nation (FINA) points system in 2005 over different swimming distances in a 50 m pool and their names taken from the website of the Finnish Swimming Association. All the female and male runners whose personal record in 2005 was better than the C level in one of the running distances from 1500 m to marathon were included in the study. In the individual sports, the selected athletes had been top-ranking at the end of the previous season. All male and female players who were members of Finnish Football League teams at the beginning of 2006 were chosen from the list posted on the website of the Finnish Football League Association (Ristolainen et al., 2010).

A sport injury questionnaire was sent at the end of the competition season to 300 top-ranking cross-country skiers, 268 swimmers, 265 long-distance runners and 367 soccer players (21 teams). In cross-country skiing 11 athletes over 35 years old and in long-distance running 3 athletes over 35 years old were excluded. From the soccer players the Åland team and foreign players were excluded, as also were three male and three female soccer teams with a low response rate (Ristolainen et al., 2010). Altogether, 639 athletes (59%) responded. Sixty-five of them returned an empty questionnaire. The final study group consisted of 149 cross-country skiers, 154 swimmers, 143 long-distance runners and 128 soccer players, 548 of whom responded to this specific question concerning the end their sport career.

Postal questionnaire

The questionnaire included separate items on training hours and frequency of training per week during both training and competition seasons as well as on the length of the training and competition seasons. On the basis of these six questions, the total number of exposure hours per year was calculated. Injury rates were reported as number of injuries per 1000 hours of exposure, combining any type of training exercise and competition. In addition, the questionnaire included questions about exercise habits and the specific reasons for ending the sport career.

The term "sport career termination" was defined as ending a career in sport at a level where the athlete has practised and actively competed (Kleiber & Brock, 1992). A sport career was also considered terminated where an athlete continued to participate in the same sports event but at a lower level (less targeted), or the where the athlete had changed the event. Severe injury was defined as loss of time from training and competition of at least three weeks duration (Arnason et al., 2004).

The term "acute sports injury" definition was modified from the determinations of Orchard and Seward (2002) and Söderman, Alfredson, and Pietila (2001) as an injury that occurs suddenly or accidentally, interrupting an athlete's training or ability to compete, or causing an identifiable trauma. An acute injury is any physical injury that keeps the athlete away from at least one training session, or competition, or needs a physician's care. The term "overuse injury" definition was modified from the determinations of Beck (1998) and Brukner and Bennell (1997) and was defined as an injury that causes pain during exercise loading without any noticeable external cause of injury. The injury gradually causes worsening pain during or after exercise. Pain becomes worse when loading is continued and may stop exercise completely.

The retrospective questionnaire was validated and reliability-tested by checking the answers to the questionnaire at an interview held one week later among 54 athletes in different sports events (Eloranta & Tittonen, 2006; Karhula & Pakkanen, 2005). The reliability of the event and training information was good or excellent (Intraclass correlation, ICC $= 0.81$–0.95, $P < 0.001$). The questions of career termination and the classification of career termination were answered identically. Following the suggestion by Karhula and Pakkanen (2005), the details of career-terminating injuries were elicited by interview.

Semi-structured telephone interview

Athletes who reported terminating their sport career because of injury in the postal questionnaire and gave permission for further study of their situation were interviewed by telephone. The interview, with a questionnaire, was conducted seven to 11 months after the postal questionnaire, in order to confirm that they had terminated their sport career and to confirm their reason for termination. Figure 1 shows the data collection and distribution of athletes among the different sports.

The interview included structured and open questions. Athletes were asked about the injury that had influenced their decision to end their sport career, and they were also asked to state any non-medical reasons. They were asked about possible injury-induced disability at work, in the home, and during leisure time, and about injury-related pain during the previous seven days and use of painkillers. The athletes were also asked about the frequency and intensity of leisure time physical exercise. Pain during the past seven days and disability at work, home and leisure time was assessed with a 10 cm visual analogue scale (VAS). The study protocol was approved by the ethics committee of the University of Jyväskylä.

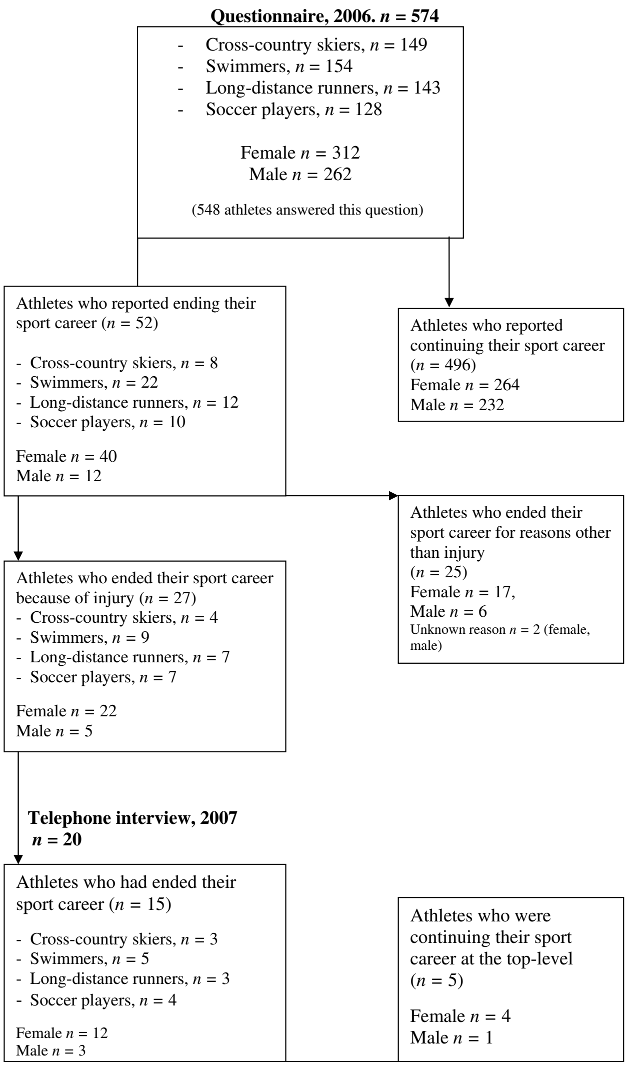

Figure 1. Description of the study group.

Statistical analysis

Statistical analyses were performed with PASW (version 18.0; SPSS Inc., Chicago, Illinois, USA). The Pearson chi-square test, *t*-tests and analysis of variance were applied to calculate statistical differences in distributions between the athletes continuing and those terminating their sport career. $P \leq 0.05$, two-tailed, was considered a statistically significant threshold.

Results

The sport injury questionnaire

According to the questionnaire, 52 (9%) out of 548 athletes reported that they had terminated their sport career. The proportion of athletes who had terminated their sport career was higher among the female (13%, 40/304) than the male athletes (5%, 12/244, $P < 0.001$). Of the athletes who had ended their sport career, 42% were swimmers, 23% were long-distance runners, 19% were soccer players and 15% were cross-country skiers. All the soccer players who did not continue playing were female. Detailed information on the study group is shown in Figure 1.

A reason for termination was given by 50 athletes. Slightly over half of them (54%, 27/50) had terminated their sport career because of an injury. Forty-one percent (11/27) reported acute injury/injuries as the main or as a contributory reason for termination (Table I). These injuries comprised severe ligament injuries and contusions. Fifty-two percent (14/27) reported overuse injury/injuries as a reason for ending their career (Table I). The injuries in this category were mainly joint injuries. Two female athletes had sustained both an acute and an overuse injury. Details of the anatomical site of injuries are given in Table I.

Athletes who reported terminating their sport career because of injury were on average two and a half years older (24.1 years vs. 21.6 years, $P = 0.006$) than athletes who continued in their sport (Table II). No difference in age was observed between female and male athletes who had ended their sport career. The incidence of acute (3.0 vs. 1.4, $P = 0.015$) and overuse injuries (2.8 vs. 1.4, $P = 0.015$) per 1000 exposure hours was higher in athletes who had terminated their career than in those who had continued. However, athletes who had terminated their sport career had participated in fewer competitions during the past year ($P < 0.001$) and in fewer training camp days ($P = 0.008$) than those who had continued their sport career (Table II). Athletes who had ended their career also reported slightly more time away from training and competition because of acute injury ($P = 0.055$) and significantly more time away

Table I. Twenty-seven athletes reported an injury as the main or as a contributory reason for ending their sport career (results from the questionnaire)

Injury type and anatomical site	*n*	%
Acute injuries		
No. of injured athletes	11	(40.7)
No. of injuries*	18	
Knee†	6	(33.3)
Shoulder	2	(11.1)
Low back	2	(11.1)
Ankle	2	(11.1)
Hip	1	(5.6)
Shin	1	(5.6)
Overuse injuries		
No. of injured athletes	14	(51.9)
No. of injuries	20	
Shoulder	6	(30.0)
Knee	5	(25.0)
Ankle	2	(10.0)
Foot	2	(10.0)
Hip	1	(5.0)
Shin	1	(5.0)
Calf	1	(5.0)
Sole	1	(5.0)
Achilles tendon	1	(5.0)

* One athlete had two acute injuries, but she reported only one anatomical site for her two acute injury.
† Three athletes had a recurrent knee injury.
Two female athletes had both an acute and an overuse injury and in the case of two athletes the injury type was unknown.

because of overuse injury ($P < 0.001$) than athletes who had continued with their sport (Table II). There were no differences in warming up, cooling down and stretching between athletes who had continued their sport and athletes who had ended their sport because of injury (Table II). Some of the athletes had to end their career despite a good ranking position.

Semi-structured telephone interview

Twenty of the 27 athletes (who had ended their sport career because of injury) agreed to a telephone interview (Figure 1). Anthropometric, training, and injury details are shown in Table II. Eleven of these athletes had terminated their sport career completely and four athletes had made a come-back but on a lower level. Five of the twenty athletes (25%) had subsequently continued their sport career on the same level as earlier. Two of these reported minor injuries only, and three had undergone surgery and recovered well enough to be able to continue their sport career. Five of the athletes who had terminated their sport career had received surgery, one skier because of a stress fracture, one swimmer because of injury in the knee region and three soccer players had undergone ACL surgery.

Table II. Characteristics of athletes who have continued and those who have terminated their sport career because of injury, adjusted for gender (mean with 95% CI [confidence interval])

	Athletes who reported to continue their sport Postal questionnaire, in 2006 *n*=496		Athletes who reported to stop their sport because of injury Postal questionnaire, in 2006 *n*=27		
	Mean	95% CI	Mean	95% CI	*P*
Age (years)	21.6	21.2–22.0	24.1	22.4–25.8	0.006
Height (cm)	174.4	173.9–174.9	174.5	172.2–176.7	0.966
Weight (kg)	66.3	65.6–66.9	65.8	62.8–68.7	0.747
BMI ($kg \cdot m^{-2}$)	21.6	21.5–21.8	21.6	20.8–22.3	0.827
Starting training (age)	8.6	8.3–8.9	10.0	8.6–11.5	0.064
Active training years (years) (at least 2 times per week)	11.2	10.8–11.6	12.0	10.3–13.6	0.363
Exposure hours (hours/year)	617	592–642	622	519–726	0.922
Competitions (*n*/year)	22.6	21.5–23.7	13.4	8.8–18.0	< 0.001
Camping days (days/year)	21.4	19.4–23.4	9.2	0.5–18.0	0.008
Resting days during training season (days/week)	1.0	0.9–1.0	1.0	0.8–1.2	0.906
Resting days during competition season (days/week)	1.3	1.2–1.3	1.4	1.1–1.6	0.436
Acute injuries per 1000 exposure hours	1.4	1.1–1.7	3.0	1.7–4.2	0.015
Overuse injuries per 1000 exposure hours	1.4	1.1–1.6	2.8	1.7–3.9	0.015
Time-loss because of acute injuries (average)	33.5	26.1–41.0	66.0	33.8–98.1	0.055
Time-loss because of overuse injuries (average)	27.4	20.9–33.8	82.7	54.8–110.5	< 0.001
Warming up before training *n*(%)*					0.197
Yes	450 (90.9)		24 (88.9)		
Occasionally	42 (8.5)		2 (7.4)		
No	3 (0.6)		1 (3.7)		
Cooling down after training *n*(%)*					0.140
Yes	408 (82.4)		19 (70.4)		
Occasionally	78 (15.8)		8 (29.6)		
No	9 (1.8)		0 (0.0)		
Stretching*					0.134
Daily	200 (40.6)		6 (22.2)		
1–3 times/week	177 (35.9)		13 (48.1)		
Less than 1–3 times/week	94 (19.1)		5 (18.5)		
No stretching	22 (4.5)		3 (11.1)		

* without gender adjustment

Altogether, 15 athletes (12 female, 3 male) were interviewed in detail (Figure 1).

All the swimmers who had ended their career had sustained a shoulder injury. The diagnoses of these injuries were various (i.e. fracture/luxation, nerve compression). One of them also had knee problems, which might have influenced her decision to end top-level swimming. All the soccer players who had terminated were female and all had sustained an acute knee ligament injury. Three of them had an ACL injury in both knees. Among the cross-country skiers the main reason for termination was stress fracture in the shin or hip region. In the long-distance runners the injuries had been sustained mainly in the knee or low back. The reasons for termination were recurrent knee meniscal injury and patella luxation. Among the athletes who reported permanently ending their sport career (9/15) contributory reasons for termination, in addition to injury, included studying ($n = 4$), lack of motivation ($n = 4$) and pregnancy ($n = 1$). In 12 athletes severe acute or overuse injury caused absence from training and competition of over 30 days duration, the average being 132 days/year [d/y] (range 30–270 days). Details of the athletes terminating their career are given in Table III.

The athletes had on average visited a physician 1.7 times during the past year because of injury, the most common of which was a knee injury. Although two-thirds of the athletes reported pain because of injury, only 40% reported taking painkillers during the past twelve months. Only one-third of the athletes had taken painkillers more than once a week. The athletes who had ended their career had an average

Table III. Description of the athletes who terminated their sport career (results from the telephone interview)

Sport event	Gender	Anatomical site	Average time-loss from training and competition (days/year)
CCS	Female × 2, Male × 1	shin, hip, pelvis	40
Swimming	Female × 4, Male × 1	shoulder region, knee	24
LDR	Female × 2, Male × 1	low back, hip, knee	80
Soccer	Female × 4	knee	110

CCS: cross-country skiing.
LDR: long-distance running.

VAS pain score at the site of injury of 2.9 during the last seven days.

In 70% of the athletes (19/27) who reported terminating their sport career because of an injury, the injury caused them mild or moderate permanent disability. The VAS scores averaged 1.5 for work-related and 2.9 for the leisure-related disability. Although most of the athletes did not have to change their occupation because of their injury, they had been on injury-related sick leave for 11.5 days on average during the past year.

Discussion

Based on our questionnaire study conducted at the end of the studied season, 27 athletes (5% of the subjects) reported that they had ended their sport career because of an injury. More female than male athletes reported terminating their sport career. Among the different sport groups, swimmers were the most prone to end their career and in all cases the reason was a shoulder injury. Because the swimmers were young, another common contributory reason for ending their sport career was to enrol in further or higher education. All the soccer players who terminated their sport career were females with severe knee injuries. The first author interviewed by telephone 20 of the 27 athletes, who had reported ending their career, 7 to 11 months after the postal questionnaire. Five of these (25%) were continuing their sport career on the same level as earlier. Severe acute and overuse injuries to the large joints, shoulder and knee were the most common reasons for career termination. Seventy percent of the athletes ending their career reported that injury caused them mild or moderate permanent disability in performing activities of daily life.

Nine percent of our athletes reported ending their sport career after one season, and in 5% of these athletes the reason for career termination was mainly or partially an injury. In the study by Kleiber and Brock (1992) 13% of their sample of athletes had a career-ending injury. Kettunen et al. (2001) found that 20% of former male athletes in different sport events reported that an injury was the main reason for ending their athletic career. Their follow-up time, 15 years, was much longer than ours, which explains the larger number of athletes terminating because of injury. During an athletic career multiple injuries or recurrent injuries at the same sites may be sustained, leading eventually to termination of the sport as a career. In our study we asked athletes about their sport career covering a 12 month follow-up of occurrence of injuries with a 7 to 11 month interval between the postal questionnaire and interview; this relatively short follow-up may explain the low number of terminating athletes. Drawer and Fuller (2001) in their study of male former soccer players reported that nearly half of the responders had ended their sport career because of injury, most commonly an overuse injury. Their study comprised purely soccer players and soccer players incur more injuries, especially acute and severe ones, than athletes in individual sports (Ristolainen et al., 2010). In Drawer and Fuller (2001) the self-report questionnaire was returned by only 37% of soccer players, which may influence the results. Most of the injuries in their study that led to early retirement from sport were knee injuries. In our study the reasons for ending the sport were divided equally between acute and overuse injuries; however, in all the soccer players the reason was an acute knee injury. Overall, our findings are in line with the earlier view that injuries play a significant role in terminating a career in sport, and in some sports events injuries may commonly be the main reason for sport career termination.

Although a high number of sport injuries occur in different sports each year, such injuries are not usually severe (Kujala et al., 2003). Severe injury rates and patterns varied by sport, gender and type of exposure (Darrow et al., 2009). Nevertheless, severe injuries also cause considerable loss of training and competition time (Hagglund, Walden, & Ekstrand, 2006; Ristolainen et al., 2010). Our athletes who ended their career had significantly more injuries per 1000 exposure hours than those who continued with the sport. On average they lost over four months training and competition time during the previous twelve months. Long absence from a regular exercise program because of severe injuries may be frustrating for an athlete. Based on the exposure hours reported, the injured athletes who had ended their sport career had continued to train despite their injuries, but they had participated in fewer competitions and training camp days than the athletes who had continued with their sport. Might it be possible to focus more specifically on helping athletes who are physically active but spend long periods away from competitions and hard training and are consequently at risk of ending their sport career, to reduce that risk? Is there a need for better rehabilitation programs or overall training methods which would improve the recovery process? This is an issue which calls for more research.

Söderman et al. (2002) reported that 78% of young female soccer players after 2–7 years of an ACL injury had stopped playing soccer, most commonly because of symptoms in their injured knee. Among our career-ending athletes all the ACL injuries had been incurred by female soccer players. Two of them had an ACL injury in both knees and three out of five athletes had undergone a knee operation because of such an injury. Most of our career-ending athletes with a knee injury reported pain and disability in squatting, and also difficulty in jumping. Despite their injuries and symptoms, most of the athletes continued at least to engage in regular leisure-time physical activity after ending their sport career.

In all the sport groups the athletes who terminated their career were somewhat older than those who continued. While the mean age of all the cross-country skiers was high, the oldest age at career termination was reported by the runners. The athletes who ended their career had more acute and overuse injuries that those who continued their career. The different loading patterns in the different sports were also associated with the injuries sustained: swimmers had shoulder region injuries, soccer players knee region injuries, and long-distance runners and cross-country skiers lower extremity injuries; the latter were mainly overuse injuries such as stress fractures. It seems that older athletes with sport event-specific injuries are at increased risk for terminating their career.

Previous studies have reported on strategies for preventing athletic injuries (Hupperets, Verhagen, & van Mechelen, 2009; Pasanen et al., 2008). The proper care and management of injured athletes is essential. This is also a challenge for the athlete's team members: how can rehabilitation and training programmes be tailored to suit the needs of the injured athlete? However, if we consider health from the viewpoint of an athlete's later years, it may be that in the case of some sports injuries the decision to end a sport career is preferable to rehabilitation and thus continuation in elite sport. In this connection it is important for the athlete to know what he/she can do to reduce the risk of injury. However, one of the most crucial issues is to find and deploy methods of preventing severe injuries that may terminate an athlete's career.

The impact of an athletic injury is dependent on a number of factors such as the nature and severity of the injury and the importance of sport in the athlete's life. Studies on athletes' fear of re-injury are few and have generally investigated athletes recovering from severe ACL injury (Chimielewski et al., 2008; Kvist, Ek, Sporrstedt, & Good, 2005; Lee, Karim, & Chang, 2008). However, fear of re-injury is an important psychological factor for athletes not returning to sport, especially for those who have sustained a severe injury (Chimielewski et al., 2008; Kvist et al., 2005; Lee et al., 2008). Increased fear of movement of an injured anatomical site could have a negative effect on the efficacy of exercise treatment and hence on rehabilitation and recovery (Silbernagel, Brorsson, & Lundberg, 2011). Athletes who reported a career-ending injury expressed significantly lower levels of life satisfaction than their non-injured counterparts (Kleiber & Brock, 1992; Petitpas & Danish, 1995). However, other studies, such as that by Perna et al. (1999), have concluded that athletes with a severe athletic injury were no less satisfied with their lives than non-injured or moderately injured athletes. In this study we did not investigate the effects of the injury on self-esteem or life satisfaction. However, many athletes reported decreased motivation as an important reason to end their sport career alongside their injury. One reason for loss of motivation may be the length of the rehabilitation process. It may not have been effective or may have taken a long time, and in consequence prevented the athlete from fully participating in training and competitions. Moreover, many athletes find that they are unable to return to their previous physical activity level (Nyland, Johnson, Caborn, & Brindle, 2002) and are therefore dissatisfied. It is possible that such athletes may have overly high or unrealistic expectations of the effects surgery for a severe injury will have and therefore are not mentally prepared for the post-operative demands of rehabilitation (Dekker, Groothoff, van der Sluis, Eisma, & Ten Duis, 2003; Thomee et al., 2006).

It may also be that gender and other factors such as embarking on further education may influence the decision to terminate a career in sport. It may be hard to combine a strict training regime with academic studies, and if an athlete's performance has been impaired as a result of injury, choosing to be educated for an alternative occupation in later life is understandable. It is also natural for athletes to want to have a family and children. For female athletes this means absence from sport during pregnancy, while after having a child only a few female athletes retain sufficient enthusiasm to continue their sport career at the top level. In our study, all the terminating athletes reported that injury was the main reason for quitting their sport career. However, because the reasons were the subjective opinions of the athletes themselves we cannot be sure that they wholly explain their early retirement from professional sport.

According to Gabbe, Finch, Bennell, and Wajswelner (2003) recall accuracy declines as the level of detail requested increases. However, terminating a sport career is such a "big thing" in an athlete's life that it is unlikely to be forgotten. A further strength of this study was the telephone interview by semi-structured questionnaire, which gave more specific information about the reasons for ending a sport career. The response rate to the postal questionnaire was low and it is to be considered a limitation in this study. Because of the low number of career-ending athletes there was insufficient power to perform many statistical analyses.

Conclusion

We found that sports injuries play a significant role in terminating a career in sport, and, in some sports events, injuries may commonly be the main reason for sport career termination. Injury prevention and adequate treatment and rehabilitation of the injuries are thus essential to avoid the long-term consequences of severe sport injuries.

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