Oslo Sports Trauma
RESEARCH CENTER

Benjamin Clarsen

Overuse injuries in sport

Development, validation and application of a new surveillance method

DISSERTATION FROM THE NORWEGIAN SCHOOL OF SPORT SCIENCES • 2014

Good surveillance does not necessarily ensure the making of right decisions, but it reduces the chance of wrong ones.

Alexander D. Langmuir
New England Journal of Medicine, 1963

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List of papers

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

I. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. Br J Sports Med 2013;47:495-502.

II. Clarsen B, Bahr R, Heymans MW, Engedahl M, Midtsundstad G, Rosenlund L, Thorsen G, Myklebust G. The prevalence and impact of overuse injuries in five Norwegian sports: Application of a new surveillance method. Scand J Med Sci Sports. Published online 30 March 2014. doi: 10.1111/sms.12223

III. Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: A prospective cohort study. Br J Sports Med 2014;48:1327-33.

IV. Clarsen B, Rønsen O, Myklebust G, Flørenes T, Bahr R. The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite athletes. Br J Sports Med 2014;48:754-60.

Summary

Introduction

Overuse injuries, defined as those without a specific, identifiable event responsible for their occurrence, may be a substantial problem in many sports. However, current surveillance methods in sports injury epidemiology studies, which rely heavily on time loss for injury definitions and severity measurement, may underestimate their true impact. This is because athletes often continue to participate in sport despite the existence of overuse injuries. The main aim of this dissertation was to develop a new method to record overuse injuries in sport, and to establish its validity by applying it in a number of different research settings.

Methods

This dissertation is based on three separate research projects. In the first project (Papers I and II) we developed the new method, including a new overuse injury questionnaire, and applied it in a 13-week prospective study of injuries among 313 athletes from five different sports: cross-country skiing, floorball, handball, road cycling and volleyball. Standard injury registration methods were also used to record all time-loss injuries that occurred during the study period. In the second project (Paper III), the new method was applied in a 30-week study of risk factors for shoulder injuries among 206 elite male handball players. In the third project (Paper IV), we modified the new method so it could be used to monitor all types of health problems, including acute injuries, overuse injuries and illnesses. It was then used in a 40-week prospective cohort study of 142 candidates for the Norwegian team at the 2012 Olympic and Paralympic Games.

Main Results

The new method captured over ten times as many overuse injuries as standard methods using a time-loss injury definition (Paper I). The area where overuse injuries had the greatest impact was the knee in volleyball where, on average, 36% of players had some form of complaint (95% CI: 32–39%) and 15% had substantial overuse problems (95% CI: 13-17%), defined as those leading to moderate or severe reductions in sports performance or participation, or time loss (Paper II). Shoulder injuries in handball were also prevalent. In paper III, the average prevalence of shoulder complaints was 28% (CI: 25% to 31%) and the average prevalence of substantial shoulder problems was 12% (CI: 11% to 13%). Significant associations were found between obvious scapular dyskinesis (OR 8.41, 95% CI: 1.47 to 48.1, $p<0.05$), total rotational motion (OR 0.77 per

5° increase, 95% CI: 0.56 to 0.995, $p<0.05$) and external rotation strength (OR 0.71 per 10 Nm increase, 95% CI 0.44 to 0.99, $p<0.05$) and shoulder injury. In Paper IV, we found that an average of 36% of athletes had health problems during their preparation for the Olympic and Paralympic Games (95% CI: 34% to 38%), and 15% of athletes had substantial problems (95% CI: 14% to 16%). Overuse injuries represented 49% of the total burden of health problems, compared to illness (36%) and acute injuries (13%).

Conclusions

The new method has good face, content and construct validity to record the full extent of overuse problems in sport, and we have demonstrated that it is feasible to apply the method successfully in studies of elite Norwegian athletes. We identified particular problem areas in a number of sports, such as the knee in volleyball and the shoulder in handball, for which continued injury prevention research focus is warranted. In the case of shoulder injuries in handball, injury prevention programs should address glenohumeral joint range of motion, external rotation weakness and scapular dyskinesis. The new method can be used to monitor not only overuse injuries, but also acute injuries and illnesses in heterogeneous groups of elite athletes.

Abbreviations

CI	Confidence Interval
F-MARC	Fédération Internationale de Football Association Medical Assessment and Research Centre
Nm	Newton metre
OR	Odds Ratio
OSTRC	Oslo Sports Trauma Research Center
ROM	Range of Motion
XC Skiing	Cross-country skiing

Introduction

Overuse injuries are a problem in many sports. Athletes exposed to high training loads, tight competition schedules and insufficient recovery are thought to be particularly at risk; especially those from sports involving repetitive movements or impacts. For example, a study of athletics athletes who train between 20 and 35 hours per week found that over one year, approximately two-thirds of athletes sustained a performance-limiting overuse injury (Jacobsson et al., 2013). Similarly, studies of elite volleyball players, who often perform over 500 jumps per week (Bahr & Bahr, 2014), report that at any given time between 29% and 44% of players have symptoms of jumper's knee (Lian et al., 2005; Bahr, 2009). While overuse injuries are more common in elite-level sports, they also occur among recreational athletes (Zwerver et al., 2011), young athletes (DiFiori et al., 2014), and even among sedentary individuals after transient increases in activity (Stovitz & Johnson, 2006).

Overuse injuries can have substantial consequences for individuals and for society in general. Pain, reduced physical performance and reduced sports participation may affect the success of athletes, teams and organisations. Furthermore, their treatment involves direct and indirect costs on individuals, employers and health-care systems. Overuse injuries are a common cause of premature retirement from sports (Cook et al., 1997; Kettunen et al., 2002), and may be symptomatic long after sporting careers are finished (Schmitt et al., 2001; Kettunen et al., 2002; Kujala et al., 2005). In less-athletic populations, they may pose a significant barrier to physical activity participation. Given the large body of evidence documenting the beneficial effects of regular physical activity (Kesaniemi et al., 2001), this is likely to have broader, long-term consequences on health and quality of life. Clearly, efforts to prevent overuse sports injuries are warranted.

In order to successfully prevent sports injuries, a systematic approach is necessary. Several models have been proposed to guide prevention research, the most fundamental of which is the four-step "sequence of prevention" of sports injuries (van Mechelen et al., 1992). The first step of this sequence involves determining the extent of the problem, including the rate and severity of injury. The second step is to identify the causes, including risk-factors and mechanisms of injury. The third step is to develop and implement an injury prevention strategy, and the fourth step is to evaluate the strategy's outcome (Figure 1).

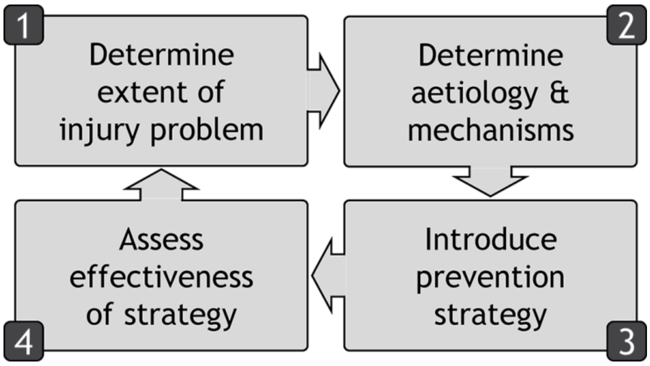

Figure 1. The "sequence of prevention" of sports injuries (adapted from van Mechelen et al., 1992)

There are an increasing number of examples where this model has been successfully applied, such as in the prevention of anterior cruciate ligament injuries in football and handball, head injuries in alpine skiing and ice hockey, ankle sprains in football, basketball, and volleyball and hamstring injuries in football and Australian Rules football (Engebretsen & Bahr, 2009). However, systematic prevention research has focussed primarily on acute, traumatic sports injuries, and little progress has been made towards the prevention of overuse injuries (van Wilgen & Verhagen, 2012).

One possible explanation for this is that the typical presentation and characteristics of overuse injuries make them difficult to record in epidemiological studies, when currently accepted methods of injury registration are used (Bahr, 2009). As accurate injury registration is a fundamental component of all steps in the sequence of injury prevention, an inability to record overuse injuries in a valid and reliable way prevents progress towards their prevention.

The following section will review the challenges of recording overuse injuries using standard injury registration methods, as well as suggestions for how it could be done differently (Bahr, 2009). First, however, it is necessary to define the term overuse injury.

Background

What is an overuse injury?

"Overuse injury" is a term firmly entrenched in the vernacular of sports medicine, used broadly to describe a class of injury caused by repeated micro-trauma rather than a single injury event (van Wilgen & Verhagen, 2012). The word "overuse" is used because the onset of this type of injury is normally precipitated by a period of inappropriate tissue loading, such as an excessive magnitude or volume of load, or insufficient recovery between bouts of loading (Bennell et al., 1996; Dye, 2005; Magnusson et al., 2010). Alternative nomenclatures in sports medicine include "gradual-onset injury" (Fuller, 2010), "overuse syndrome" and "sports disease" (Timpka et al., 2014b), while in occupational medicine the terms "cumulative trauma disorders" or "repetitive strain injuries" are often used (Rempel et al., 1992; Yassi, 1997).

Many different types of sports-related overuse injury can occur across a wide variety of body structures, including bones, tendons, joints, ligaments, muscles and fascia, bursae, and nerves (Table 1)(Brukner & Khan, 2012).

Table 1. Common types of overuse injuries in sport (adapted from Brukner and Khan, 2012)

Site	Type of overuse injury	Common examples in sport
Bone	Bone strain/stress reaction/stress fracture Osteitis, periostitis Apophysitis	Metatarsal stress fracture in running Medial tibial stress syndrome in running and dancing Osgood-Schlatter lesion
Tendon	Tendinopathy (includes paratenonitis, tenosynovitis, tendinosis, tendinitis)	Patellar tendinosis in volleyball ("jumper's knee") Achilles tendinosis
Joint	Synovitis Labrum injuries Chondropathy	SLAP lesions in throwing athletes Functional acetabular impingement of the hip in football
Ligament	Chronic degeneration/micro-tears	Ulnar collateral ligament injury in baseball
Muscle/Fascia	Chronic compartment syndrome Delayed-onset muscle soreness Fasciitis/fasciosis	Illiotibial band syndrome in running ("runner's knee")
Bursa	Bursitis	Trochanteric bursitis in race walking
Nerve	Altered neuromechanical sensitivity Entrapment	Ulnar neuropathy in cycling ("handlebar palsy")

For most types of overuse injury the precise pathogenesis is not fully understood (Warden et al., 2006; Magnusson et al., 2010), and current models are based on theory – particularly of bone and tendon injuries. For bone, the process of overuse injury is thought to occur along a continuum, ranging from mild stress reactions to complete stress fractures (Diehl et al., 2006; Warden et al., 2006). Repetitive loading of bone tissue leads to microdamage at the sites which are maximally stressed. Normally, this process is asymptomatic; repair and remodelling occurs according to Wolff's law, resulting in a stronger bone (Woo et al., 1981). However, in certain situations, such as when the magnitude or frequency of loading is excessive, microdamage production exceeds repair, resulting in propagation of damage and eventual macroscopic failure of the bone (Bennell et al., 1996; Diehl et al., 2006).

Similar theories of a pathology continuum in response to excessive loading exist for tendons (Cook & Purdam, 2009), where the balance of loading and recovery has been particularly highlighted as a causative factor (Magnusson et al., 2010). Mechanical loading of tendons leads to increased collagen synthesis, which peaks after 24-72 hours but remains elevated for up to 5 days (Langberg et al., 1999b; Langberg et al., 2000; Miller et al., 2005). Loading also causes collagen degradation, which occurs earlier and to a greater extent than collagen synthesis (Langberg et al., 1999a). Therefore, as illustrated in Figure 2, there is an initial net degradation of collagen turnover in the initial 18-36 hours following exercise, after which a net synthesis occurs. If recovery between loading sessions is inadequate collagen degradation can accumulate, leading to overuse injury.

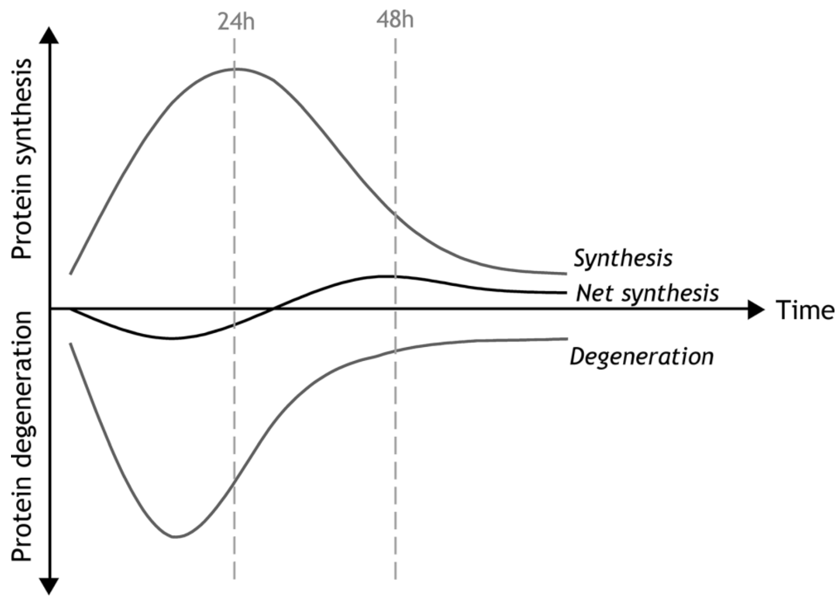

Figure 2. Schematic representation of collagen synthesis and degradation in tendon tissue following exercise (adapted from Magnusson et al., 2010)

Tendon pathology may also be caused by under-loading, which has been shown to cause similar cell and matrix changes to those seen as a response to overload, resulting in a reduction in the mechanical integrity of the tissue (Cook & Purdam, 2009). This may explain why certain "overuse" injuries also occur in inactive populations after transient increases in activity (Stovitz & Johnson, 2006).

Definitions of overuse injury in epidemiology

In injury prevention research there is a need for operational definitions that are simple, pragmatic and consistently applicable across a range of settings (Fuller, 2010). Theoretical definitions of injury are also necessary to assist researchers to classify difficult cases (Langley & Brenner, 2004).

Recent definitions of sports injury include that they are: (1) physical complaints or impairments resulting from participation in sports or physical activity, and (2) caused by a transfer of energy at a rate or in an amount that exceeds the body's ability to maintain its structural or functional integrity (Fuller, 2010; Timpka et al., 2014a; Timpka et al., 2014b). Sports injuries are typically classified as being either an acute (traumatic) or an overuse injury. Theoretically, the difference between the two types is the nature of the energy transfer that caused them. For acute injuries the energy transfer is instantaneous, whereas for overuse injuries it is accumulated over time (Finch & Cook, 2013).

Operationally, however, sports injuries are classified based on whether they can (acute) or cannot (overuse) be linked to a specific, clearly identifiable event such as a fall or a collision (Fuller et al., 2006; Turner et al., 2012; Timpka et al., 2014a).

It is important to recognize the potential conflict between the theoretical and operational definitions of overuse injury. The operational definition is, in effect, made by exclusion and does not consider the actual cause of the injury. This may lead to injuries caused by habitual under-use, or that are primarily driven by psychosocial factors, to be classified as overuse injuries when clearly they are not. Nevertheless, in sports injury epidemiology studies, these conditions would be regarded as overuse injuries as their onset cannot be linked to one specific, clearly identifiable trauma.

Application of this operational definition is normally straightforward, as for most sports injuries the presence or absence of an inciting event is easy to determine. However, in certain cases it may be a challenge. For some overuse injuries, symptom onset can be rapid despite being preceded by a subclinical process of cumulative tissue damage. For example, pain may develop over the course of a single training session, or even instantaneously during a "normal" loading situation, such as when an athlete feels the onset of a stress fracture in the foot during one particular step (Bahr, 2009). In such cases, there is a substantial risk of misclassification. Certain authors have attempted to solve this challenge by subclassifying overuse injuries into those with a rapid onset and those with a gradual onset (Junge et al., 2008; Jacobsson et al., 2013; Timpka et al., 2014a). However, even when this is done the same difficulties arise in differentiating between rapid-onset overuse injuries and acute injuries. In these cases the injury recorder needs to make a clinical judgement based on the theoretical definition of overuse and acute injuries. In particular, it should be considered whether the energy transfer occurring at the perceived moment of injury was sufficient to damage previously healthy, intact tissue.

It should also be noted that in some epidemiology studies the term "overuse" is used as a specific injury diagnosis category (comparable to, for example, a ligament sprain), rather than as a mechanism-based injury classification. In order to aid the interpretation and comparability of research, this practice has been discouraged (Roos & Marshall, 2014).

Injury surveillance methods in sports medicine epidemiology

Valid surveillance data is a prerequisite of much injury prevention research (van Mechelen et al., 1992). It is also important that studies use similar methods to collect and report injury data to facilitate meaningful interpretation and comparison of results. There is substantial documentation that the results of sports injury studies are highly influenced by injury definitions, data collection methods, and reporting standards (van Mechelen et al., 1992; Finch, 1997; Junge & Dvorak, 2000; Brooks & Fuller, 2006; Bjørneboe et al., 2011; Flørenes et al., 2011). For example, Brooks & Fuller (2006) demonstrated that defining an injury as *any physical complaint causing a player to be absent from training or competition for one or more days* lead to almost twenty times as many injuries being recorded than when an injury was defined as *a physical complaint leading to the athlete requiring surgery*. Clearly, data collected using different injury definitions cannot be compared.

Similarly, studies using prospective and retrospective data collection methods are also difficult to compare, due to the effects of recall bias. For example, Junge and Dvorak registered injuries among 264 football players prospectively over one year, and then asked players to recall the injuries they had sustained during the same period. Nearly two thirds of injuries registered prospectively were not remembered during the retrospective registration, including several severe injuries such as fractures. When injuries were recalled, discrepancies also existed between the severity recorded by the prospective and retrospective methods (Junge & Dvorak, 2000).

The problems caused by the lack of uniform surveillance methods have been recognised and discussed in the literature for many years, and in 2005 the first efforts were made to reach a broad international consensus on injury registration methodology (Bahr, 2009; Fuller, 2010). A meeting of experts in epidemiology and sports medicine research was hosted by the Fédération Internationale de Football Association Medical Assessment and Research Centre (F-MARC), with the aim of establishing definitions, data collection methods and reporting standards for studies of football injuries. It was also hoped that the recommendations from the meeting would provide the basis for studies of injuries in other sports (Bahr, 2009).

The resulting consensus document (Fuller et al., 2006) has had a considerable impact on the field of sports injury epidemiology. It was published in three different journals, and has been cited 318 times since its publication (Thompson-Reuters Web of Science citation search, 6th June 2014). This impact is not limited to football; sport-specific adaptations have been published for rugby union, rugby league, tennis, thoroughbred horse racing and athletics (Fuller et al., 2007; King et al., 2009; Pluim et al., 2009; Turner et al., 2012; Timpka et al., 2014a), and important elements of the F-MARC consensus statement, such as injury definitions and severity measures, have been applied in studies of a diverse range of other sports, such as alpine and freestyle skiing, athletics, baseball, biathlon, equestrian, futsal, ice hockey, road cycling, rock climbing, ski cross, snow kiting and wrestling.

Given the widespread adoption of the recommendations made in the F-MARC consensus statement, they could currently be regarded as "standard" injury registration methods. The following section will analyse several of the key recommendations, with particular focus on their application to the study of overuse injuries.

Injury definitions

The F-MARC consensus statement defines an injury as:

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

"Medical attention" refers to an assessment of a player's medical condition by a qualified medical practitioner. The term "future" refers to any time after the onset of injury, including the day of injury.

In effect, therefore, there are three alternative definitions of a recordable injury: (1) any physical complaint, (2) medical attention and (3) time loss. These could be placed in a hierarchy ranging from broad to narrow, based on the number of incidents they are likely to capture, as shown in Figure 3.

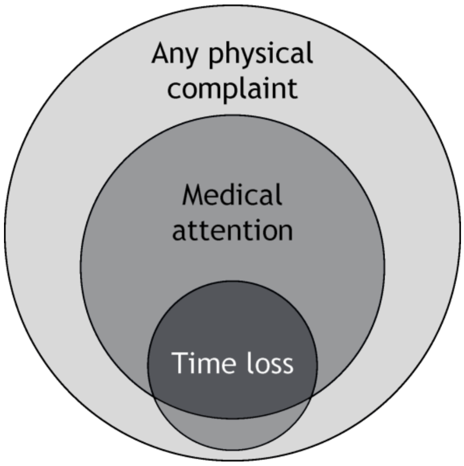

Figure 3. Interactions between various definitions of injury recommended in the F-MARC consensus statement. Circle-size represents the relative number of incidents likely to be registered (not to scale).

Time loss

Although the consensus statement recommends the use of all three, in practice time loss is the most commonly used definition, particularly in longer-term surveillance programs in team sports (Brooks et al., 2005; Olsen et al., 2006; Ekstrand et al., 2011; Bjørneboe et al., 2014). It represents the narrowest definition, being the one that is likely to record the fewest incidents.

One of the assumed strengths of the time-loss definition is that an inability to fully participate in planned training and competition is easy to identify. It is therefore considered to be relatively reliable, allowing for the comparison of data among different teams and across multiple seasons. As no medical expertise is needed to apply a time-loss definition, injury occurrence (albeit not diagnosis) can be recorded by coaches, parents or other non-trained individuals. This may be of particular benefit in studies of young and recreational athletes. It is also argued that using a time-loss definition reduces the burden on injury recorders while still capturing the most relevant injuries (Orchard & Hoskins, 2007).

However, despite its widespread use there are several limitations to the time-loss definition. First, athletes often continue to train and compete despite the existence of injury. Common management strategies, such as the use of analgesic medications and anaesthetics, modification of the type or intensity of training, and delaying treatment or rest until the off-season may lead to a large number of injuries being missed when a time-loss definition is used. This is particularly relevant for overuse injuries, which typically begin gradually and have fluctuating symptoms over time (Figure 4).

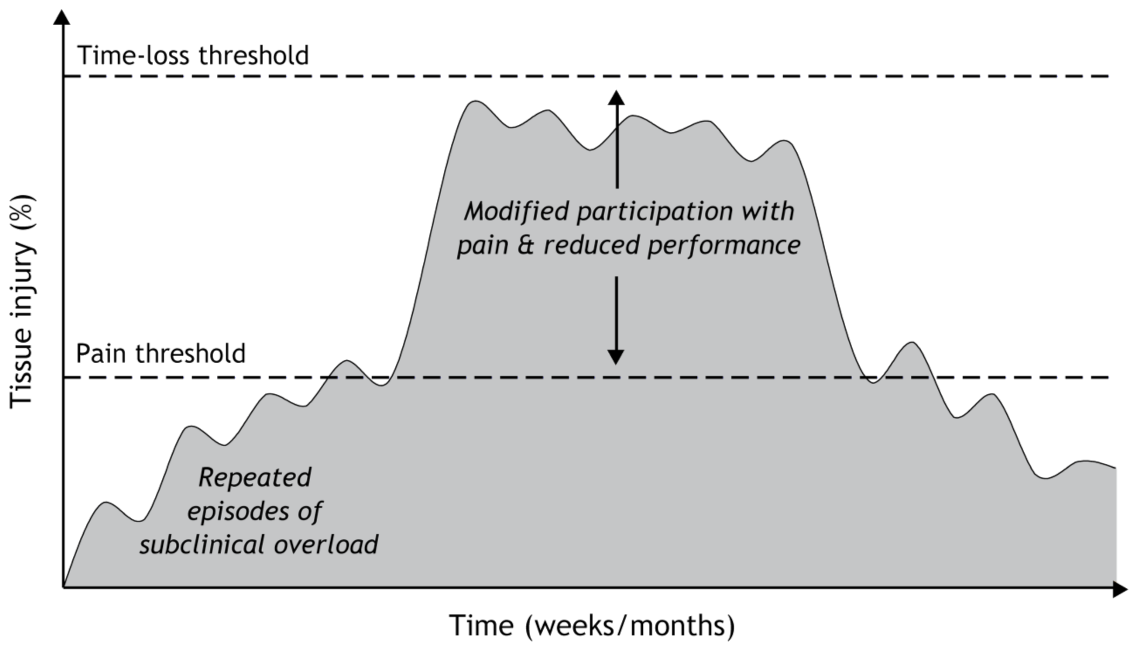

Figure 4. Hypothetical model of overuse injury (adapted from Bahr, 2009 and Leadbetter, 1992)

A second limitation of the time-loss definition is that "an inability to fully participate in training and/or competition" is difficult to apply in studies of individual sports. In team sports, this may be relatively straight-forward; a player can either take part in planned training sessions or they cannot. In contrast, individual athletes have a far greater scope to modify their own training in response to injury. For example the mode, intensity, frequency or volume of exercise can all be adjusted such that the question of whether "normal" training has been maintained may be very difficult to answer. For example, a distance runner with ITB syndrome may avoid running hills, but can perform all their normal training on the flat. In fact, this is also becoming a problem in team sports, particularly at an elite level where it is increasingly common for players to have individualized training programs with a blurred line between injury prevention training and rehabilitation. Consistent application of the definition may therefore be difficult in this setting, as well.

A third limitation which is particularly relevant for team sports is that the threshold for time loss varies according to the importance of the injured player and the time of the season in which the injury occurs. For example, star players are less likely to miss time due to minor injury during important phases of the season.

Therefore, at any point in time only a small proportion of injuries may satisfy the criteria for a recordable injury. This has been referred to as the "tip of the iceberg phenomenon" (van Mechelen et al., 1992), and can be illustrated in the following hypothetical example of overuse injuries sustained by players in a team over the course of a season (Figure 5):

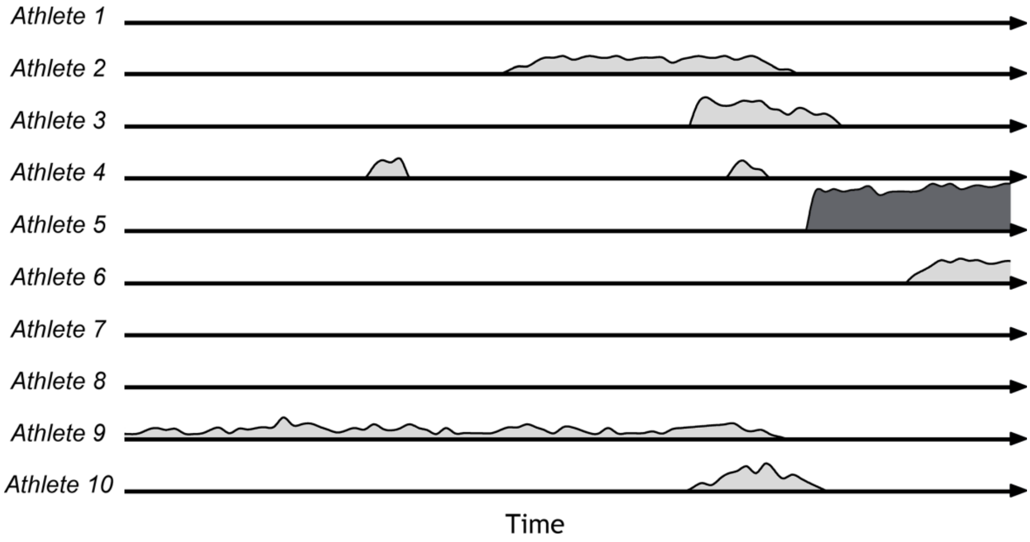

Figure 5: Hypothetical example of results from a prospective cohort study on symptoms of pain and reduced function among 10 athletes, with only one case leading to time loss (dark area) (adapted from Bahr, 2009)

In this example, although a total of eight episodes of pain and reduced function are observed, only one would have been detected using a time-loss definition.

Medical attention

The reporting of medical-attention incidents is recommended in a majority of consensus statements as this is likely to capture a far greater number of conditions than time loss and will therefore provide a more complete picture of the true burden of injury and illness (Hodgson et al., 2007). This may be of particular importance when the aim of surveillance is to assist in the allocation of medical resources within teams or organizations (Meeuwisse & Love, 1997). However, in many research contexts the potential for systematic bias makes this definition unreliable (Orchard & Hoskins, 2007). For example, in a study of World Cup alpine skiers a large proportion of medical-attention injuries were missed by team medical staff as skiers often travelled for long periods without medical support or had to relate to a variety of different practitioners throughout their season (Flørenes et al., 2011). Non-uniform and inconsistent access to medical support is also likely to be a problem in amateur and youth sports, preventing the reliable use of a medical-attention definition. Even in a professional team-sport environment, systematic differences between recorders' interpretation of what constitutes medical attention are likely. Furthermore, there may be differences in the interpretation of who is qualified to provide medical attention between different sports and cultures, where ancillary practitioners such as physiotherapists, chiropractors, athletic trainers and massage therapists have varying qualifications and status. The use of a medical-attention definition may also place large demands on team medical staff due to the large number of conditions likely to be recorded; this would likely compromise completeness and accuracy of the data.

All complaints

"All complaints" is the most common consensus-recommended surveillance definition, but there are relatively few examples of it being used in its true form (i.e. registration of *all* medical problems, including those that do not lead to medical attention). Because surveillance studies have traditionally used medical staff to record data, they are unlikely to be aware of conditions not needing medical attention. However, the strengths and limitations of this definition are similar to those of medical attention; data may be a good representation of the total burden of injury and illness, but their reliability may be suspect. One of the major problems is that data are subject to systematic bias due to each collector's interpretation of what constitutes a recordable complaint. For example, a physiotherapist on one team may consider delayed-onset muscle soreness as a recordable complaint whereas one on another team may not, considering it a normal response after heavy training.

Injury severity

The severity of sports injuries can be measured in many ways, such as the nature of injury, the duration and nature of medical treatment, sporting time lost, working time lost, permanent damage and monetary cost (van Mechelen, 1997). However, the most common way of expressing severity is the duration of sporting time lost, recommended by the F-MARC consensus statement as:

The number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection.

The following guidelines are given for recording injury severity:

The day on which an injury occurs is day "zero" and is not counted when determining the severity of an injury. Therefore, if a player cannot participate fully on the day of an injury but is available for full participation the next day, the incident should be recorded as a time-loss injury with a severity of "0 days."

The average and median severity of injuries should be reported in days, together with the distribution of injuries grouped according to their severity; namely: slight (0 day), minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (>28 days) and career ending injuries.

The advantages of using this measure of injury severity are similar to those of the time-loss injury definition; the occurrence of time loss is relatively easy to define (at least for team sports), and its duration can be recorded by coaches, parents or athletes themselves. It is therefore considered to be a reasonably reliable measure applicable across a range of research settings. Furthermore, when severity is reported in the absolute number of days it is possible to calculate the mean and median values, which may be good outcome measures in risk factor and injury prevention intervention studies (Fuller, 2010).

However, there are a number of assumptions underlying this approach which make it difficult to apply to overuse injuries. Most importantly, the approach is based on an assumption that injuries that do not lead to time loss are inconsequential. While this may hold true for acute injuries, it is not uncommon that overuse injuries last for months or years and have serious consequences on athletic performance, without leading to time loss. In these cases, classifying the injury as slight (0 days) is clearly a poor reflection of its real impact.

This approach is also based on an assumption that the number of days of time loss associated with an injury are consecutive. When overuse injuries do lead to time loss, they are often characterised by brief periods of time loss interspersed with attempts to resume sports participation (Figure 6). In these cases, the duration of time loss does not reflect the injury's true severity.

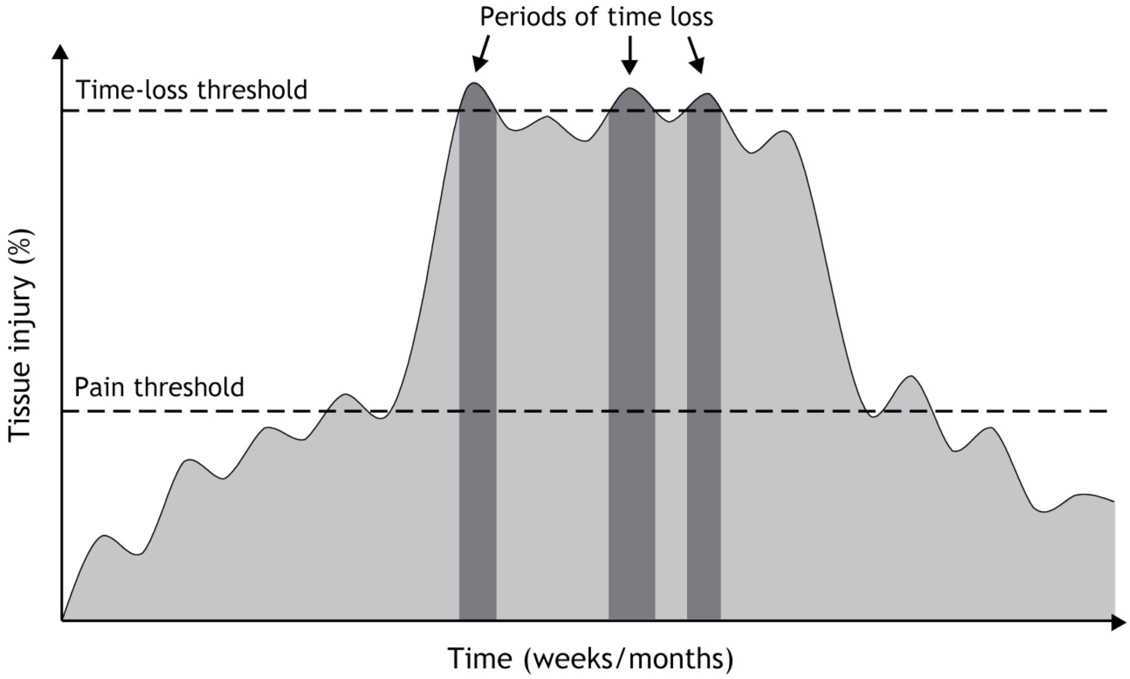

Figure 6. Hypothetic model of an overuse injury that leads to three periods of time loss (dark areas)

Outcome measures

The F-MARC consensus statement recommends that the rate of injury should be expressed as the *incidence* of injury, defined as the number of new injuries per 1000 hours of match and training exposure.

This has traditionally been seen as the optimal method for describing the rate of injury, as expressing it as a function of the time at risk of injury (i.e. exposure time) allows for objective comparison of injury data between studies of different size and duration (de Loës, 1997). However, as incidence measures only account for *new injuries* during the course of a study, it is a poor measure for overuse conditions (Bahr, 2009). This is because overuse injuries are often long-standing problems, and a substantial percentage of those present in a group of athletes are likely to already exist at the start of a study. For example, in a study of patellar tendinopathy among athletes from various sports, the average duration of symptoms was 32 months, and only 25% of the injuries registered in the study had developed during the same season (Lian et al., 2005). It is therefore likely that incidence measures will substantially under-represent the true extent of overuse injury.

An alternative approach to overuse injury surveillance

As outlined above, there are several challenges when recording overuse injuries using standard surveillance methods. In 2009, Bahr made a number of recommendations for an alternative approach, in order to account for these challenges.

First, studies should have a prospective design, in which a predefined cohort of athletes are monitored using serial measurements of symptoms and function (Figure 7). Regular measurement, for example every week, would allow for the consequences of overuse injury to be tracked over time. This design, sometimes called a panel study (Rothman et al., 2008), is not commonly used in sports medicine. However, it is often used in epidemiological studies of chronic diseases, such as asthma and diabetes (Parsons et al., 2014; Centers for Disease Control and Prevention, 2014).

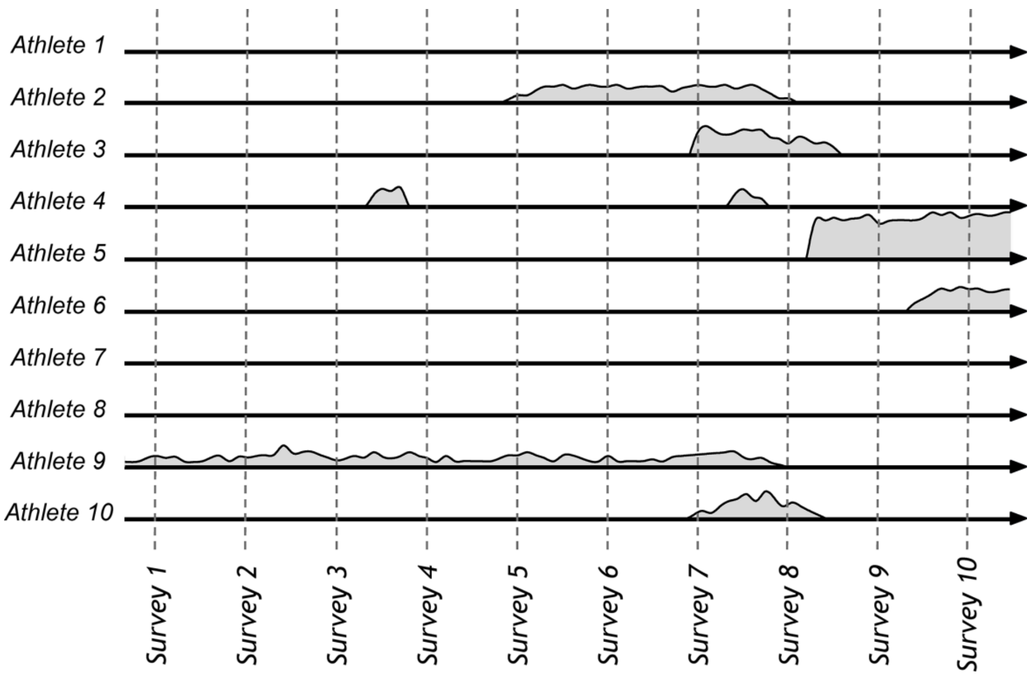

Figure 7. Prospective study design to record overuse injuries in sport, suggested by Bahr (2009)

Second, a valid instrument that can record overuse injuries among groups of athletes is necessary to conduct studies with this design. Although there exists numerous patient-reported health outcome measures applicable to overuse sports injuries, such as the Victorian Institute of Sport Assessment Scale for Achilles and patellar tendinopathies (Visentini et al., 1998; Robinson et al., 2001), the Copenhagen Hip and Groin Outcome Scale (Thorborg et al., 2011) and the Constant-Murley Score for the shoulder (Constant & Murley, 1987), these instruments are joint- or area-specific and were designed for use among general patient populations, principally to measure the outcome of treatment interventions rather than for monitoring large groups of athletes. Ideally, one instrument could be developed to monitor all types of overuse injuries in all anatomical areas.

Third, in order to be sufficiently sensitive to capture overuse injuries, the new instrument should record all physical complaints related to sports participation. The degree of symptoms and functional consequences of injury should be monitored, and these measures should form the basis of severity measures, rather than time loss from sports.

Finally, the most appropriate measure to reflect the extent of overuse injuries is prevalence, rather than incidence. Prevalence refers to the proportion of athletes affected by problems at any given point in time. If measured repeatedly, the average prevalence over the course of a season could be calculated, and various parts of the season compared.

Overuse shoulder injuries in handball

Handball is played all over the world, particularly in Europe where it is one of the most popular team sports. It has been an Olympic sport since 1972. In 2013 there were 114,285 registered players in Norway, which ranks it as the third most popular organized sport behind football (366,716 players) and skiing (179,447 skiers) (Norges Idrettsforbund, 2014). It is a high-paced, physiologically demanding sport involving frequent contact between players, rapid direction changes, cutting and jumping (Vlak & Pivalica, 2004; Povoas et al., 2012). Not surprisingly, there is a high rate of acute lower limb injuries (Nielsen & Yde, 1988; Seil et al., 1998; Junge et al., 2006; Olsen et al., 2006; Langevoort et al., 2007; Møller et al., 2012).

Overuse shoulder injuries are also considered to be a particular problem in handball. Overarm throwing is one of the key activities in the sport, and as fast and precise throwing is an advantage, much training is focused towards enhancing throwing technique and velocity (van den Tillaar & Cabri, 2012). Elite players, who perform up to 1200 throws in a normal training week (Prestkvern, 2013), may be particularly at risk of overuse shoulder injury. Studies of elite male players in Germany have found that the shoulder is the most common site of overuse injury (Seil et al., 1998), and that 40% of players experienced shoulder pain during a six-month period (Gohlke et al., 1993). Similarly, a cross-sectional study of female players in the Norwegian elite series found the prevalence of shoulder pain was 36%, with 59% of players reporting a history of shoulder pain (Myklebust et al., 2013). In a majority of cases, players reported having to modify their training behavior due to shoulder pain. However, relatively few cases led to time loss. This may explain why previous prospective cohort studies of handball injuries which have used a time-loss definition have failed to identify shoulder injuries to be a particular problem in the sport (Olsen et al., 2006; Langevoort et al., 2007).

The causes of overuse shoulder injuries in handball

Identification of the causes of injury is an important step in the sequence of prevention, as this can guide the development of effective prevention programs (van Mechelen et al., 1992). Research to establish the causes of sports injuries can be guided by a model originally described by Meeuwisse (Meeuwisse, 1994), and later expanded by Bahr and Krosshaug (Bahr & Krosshaug, 2005). According to this model (Figure 8), knowledge about why certain athletes may be at risk of injury (risk factors) as well as how injuries occur (injury mechanisms) is necessary to fully understand the causes of sports injuries. Risk factors are typically separated into those internal and those external to the athlete.

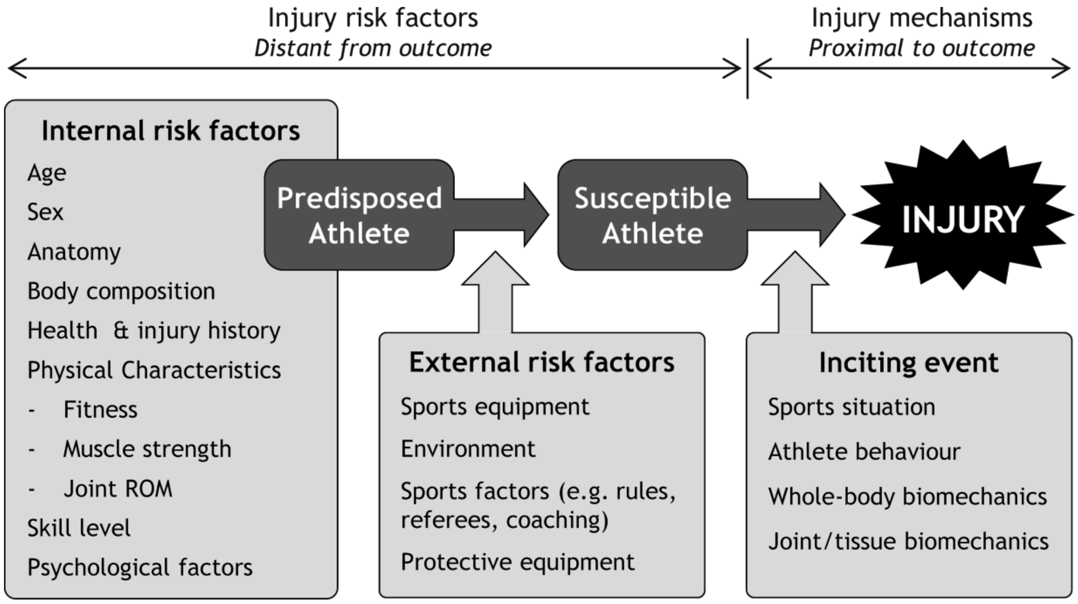

Figure 8. A comprehensive model of injury causation (adapted from Bahr and Krosshaug, 2005)

While research on the causes of overuse shoulder injuries in handball is limited, several studies have investigated internal risk factors, including glenohumeral joint range of motion (Myklebust et al., 2013; Almeida et al., 2013), and rotator cuff muscle strength (Edouard et al., 2013). These factors were selected based on previous research of other overhead and throwing athletes, in particular baseball pitchers, as the causes of injury are assumed to be similar.

Glenohumeral joint range of motion

Studies comparing the dominant and non-dominant shoulders of overhead athletes consistently report a systematic loss of internal rotation and gain in external rotation in the dominant shoulder

(Ellenbecker et al., 1996; Ellenbecker et al., 2002; Trakis et al., 2008; Reeser et al., 2010; Wilk et al., 2011; Manske et al., 2013). This is regarded to be a normal adaptation to repeated throwing (Kibler et al., 2013a), due to contracture of the posterior joint capsule, bony adaptation of the humerus and/or changes in external rotator muscle tone (Cools et al., 2008). However, several studies have found that large glenohumeral internal rotation deficits in the dominant compared to the non-dominant shoulder is a significant risk factor for shoulder injury (Ruotolo et al., 2006; Myers et al., 2006; Shanley et al., 2011). This is thought to be due to an alteration of glenohumeral joint kinematics, leading to increased stress on capsular structures and the glenoid labrum (Burkhart et al., 2003a; Kibler et al., 2013a).

Normally, internal rotation deficits in throwers' shoulders are offset by increased external rotation, such that the total rotational motion remains unchanged (Ruotolo et al., 2006; Myers et al., 2006; Kibler et al., 2013a). However, when the amount of internal rotation loss is not offset by an external rotation gain, the total rotational motion of the glenohumeral joint is reduced. This is thought to increase stress on the static glenohumeral stabilisers (Manske et al., 2013), and has been found to be a risk factor for shoulder injury among baseball pitchers (Ruotolo et al., 2006; Wilk et al., 2011). Wilk et al. (2011) also found that pitchers with *increased* total rotational motion in their dominant compared to their non-dominant shoulders had a greater risk of injury, particularly those with more than 176° of total rotational motion in their throwing shoulder. This was attributed to excessive demands being placed on dynamic and static shoulder stabilisers.

The two studies investigating the relationship between glenohumeral joint range of motion and shoulder injury among handball players report conflicting results. Myklebust et al. (2013) found no association between range of motion measures and injury, whereas Almeida et al.(2013) found that an internal rotation deficit in the throwing shoulder was a significant injury risk factor.

Shoulder strength

Weakness of the rotator cuff musculature, particularly the external rotators, may also be a risk factor for shoulder injuries in throwing athletes (Wilk et al., 2002). External rotator weakness may lead to shoulder injury due to reduced dynamic stabilization of the glenohumeral joint and reduced dissipation of the kinetic energy created by the internal rotators during the late cocking and deceleration phases of throwing (Magnusson et al., 1994; Wilk et al., 2002; Byram et al., 2010). While external rotator weakness may be common among both injured and uninjured throwers (Wilk et al., 1993; Magnusson et al., 1994; Donatelli et al., 2000; Hurd et al., 2011b), a prospective study of baseball pitchers found a significant association between external rotation weakness and shoulder injury (Byram et al., 2010). The same study also found that the ratio of external to internal rotation strength, as well as abduction weakness in the scapular plane were risk factors for shoulder injury. Abduction in the scapular plane is thought to test the function of the supraspinatus muscle (Reinold et al., 2007), which plays an important role in dynamic glenohumeral stability. Supraspinatus weakness has also been linked to shoulder injuries in two other studies of baseball pitchers (Trakis et al., 2008; Tyler et al., 2014).

Only one study has investigated the relationship between rotator cuff strength and shoulder injuries among handball players (Edouard et al., 2013). While no association was found between absolute external rotation strength values and injury, a dynamic imbalance between internal and external rotators, measured in an isokinetic dynamometer, was identified as a significant risk factor.

Scapular dyskinesis

Scapular dyskinesis, which refers to an impairment of the normal control of scapular motion, may also be a risk factor for shoulder injuries in throwing athletes (Kibler, 1998; Burkhart et al., 2003b; Kibler et al., 2013b). As the scapula's position is a key determinant of glenohumeral joint alignment, impaired scapular control may directly contribute to primary or secondary impingement syndromes, affect rotator cuff muscle function, and increase stress on passive joint structures such as the glenoid labrum (Kibler & Sciascia, 2010).

Evidence that scapular dyskinesis is a risk factor for shoulder injuries is scarce. To our knowledge, the only study to find an association between dyskinesis and shoulder injury is one of rugby players (Kawasaki et al., 2012). As the authors recognize, rugby is a collision sport which mainly involves underarm passing and kicking, and the mechanism of shoulder injury is likely to differ substantially from in overhead throwing sports.

Scapular dyskinesis is common among overhead athletes (Myers et al., 2005; Oyama et al., 2008; Madsen et al., 2011), but evidence of an association with shoulder injury is lacking (Kibler et al., 2009; Tate et al., 2009; Myers et al., 2013; Struyf et al., 2014).

Aims of the dissertation

The overall aims of this PhD project were to develop a new method to record overuse injuries in sport based on Bahr's conceptual suggestion (Bahr, 2009), and to establish its validity by applying it in a number of different research settings. In doing so, we were able to address a number of other research questions, including:

1. To what extent do surveillance data on overuse injuries collected using the new method differ from those collected using standard surveillance methods? (Paper I)

2. What is the prevalence and impact of overuse injuries among athletes from various sports in Norway? (Papers II-IV)

3. Are scapular dyskinesis, glenohumeral joint range of motion and shoulder strength risk factors for shoulder injuries among elite male handball players? (Paper III)

4. Can the new method be modified to monitor all types of health problems in groups of elite athletes? (Paper IV)

Methods

The four papers included in this dissertation were the result of three separate research projects. In the first project we developed the new method, which involved the creation of a new questionnaire and the determination of new outcome measures to describe the extent and severity of overuse injuries in sports. We then tested it against standard surveillance methods in a 13-week prospective cohort study of 313 Norwegian athletes from 5 different sports. This led to two separate papers: The first (Paper I) describes the questionnaire's development and its psychometric properties, and contrasts the results of the new method with traditional surveillance methods. In the second paper (Paper II), we compared the prevalence and impact of overuse injuries in each of the five different sports.

In the second project, the new method was applied in a 30-week prospective cohort study of risk factors for shoulder injuries among 206 elite male handball players (Paper III).

In the third project (Paper IV), we modified the new method so it could be used to monitor all types of health problems, including acute injuries, overuse injuries and illnesses. It was then used in a 40-week prospective cohort study of 142 candidates for the Norwegian team at the 2012 Olympic and Paralympic Games.

Participants

All participants included in this dissertation were athletes competing on a national and/or international level. In the first project (Papers I & II), 313 athletes from 5 sports were recruited to test the new method; 46 cross-country skiers, 98 road cyclists, 50 floorball players, 55 handball players and 65 volleyball players. This was a convenience sample, with participating teams identified through the research group's personal contact network. As such, there was variation in age, gender distribution and athlete experience between sporting groups.

The second project (Paper III) included all teams in the Norwegian elite handball league for men (Postenliga) in the season 2011-12. We visited every team during preseason training sessions and invited all players into the study. A total of 206 of the 230 players in the league were in attendance and agreed to participate.

In the third project (Paper IV) we aimed to include all candidates for the Norwegian team at the 2012 London Olympic and Paralympic Games. We asked the coaches of the national teams in all candidate sports to provide a list of athletes who had the potential to qualify. The final list included 143 athletes, 142 of whom agreed to participate. This included 116 Olympic and 26 Paralympic candidates. The Olympic sports included archery (n=1), athletics (n=22), beach volleyball (n=6), boxing (n=2), cycling (n=12), handball (n=24), kayak (n=7), rowing (n=13), sailing (n=8), shooting (n=5), swimming (n=10), taekwondo (n=3), weightlifting (n=1) and wrestling (n=2). The Paralympic sports included archery (n=1), athletics (n=1), boccia (n=1), cycling (n=2), equestrian (n=4), sailing (n=4), shooting (n=7), swimming (n=3) and table tennis (n=3).

In all projects, athletes were identified as potential participants due to their membership of a particular sports team or program. There were no exclusion criteria. We made initial contact with teams through coaches, but athletes were invited to participate on an individual basis. Written and verbal information was provided about the aims of the project, the procedures involved and any potential risks involved with participation. All studies were reviewed by the South-Eastern Norway Regional Committee for Research Ethics, and all athletes included in this dissertation completed informed consent forms (Appendix I).

Development and testing of the new method

As we were unable to identify any existing questionnaires designed to record the symptoms and consequences of overuse injuries in any anatomical area, we developed a new questionnaire called the Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire (Appendix II).

The questionnaire was developed during a series of group meetings at OSTRC, attended by sports physiotherapists, medical practitioners, sports injury epidemiologists, athletes and experts in questionnaire design. During the initial meetings, we prepared a draft list of questions including items on injury symptoms, the consequences of overuse injuries on sports participation and performance, and the degree to which injury affected physical functions such as jumping, lifting and throwing.

We then conducted interviews with athletes and team clinicians from a variety of sports to determine whether they considered the draft questions to be understandable and appropriate for measuring overuse injuries in their sport. There was general agreement that pain, limited participation in training and competition, and reduced sporting performance were all important consequences of overuse injury. However, in several instances athletes thought that specific questions on physical function were irrelevant. For example, cross-country skiers felt that questions relating to jumping and throwing ability were not good measures of injury consequences for their sport.

We therefore chose to eliminate all questions related to particular functional activities and concentrate on recording pain and the consequences of injury on sports participation and sporting performance. After a second round of athlete interviews, we agreed upon four questions that serve as the basis for the assessment of any given anatomical area (Figure 9). We chose to use the term 'problem' rather than 'injury," because there was a much greater variation in athletes' interpretation of the term 'injury.'

Oslo Sports Trauma Research Center Overuse Injury Questionnaire

Please answer all questions regardless of whether or not you have problems with your knees. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

The term "knee problems" refers to pain, ache, stiffness, swelling, instability/giving way, locking or other complaints related to one or both knees.

Question 1

Participation in normal training & competition

Have you had any difficulties participating in normal training and competition due to knee problems during the past week?

- ☐ Full participation without knee problems
- ☐ Full participation, but with knee problems
- ☐ Reduced participation due to knee problems
- ☐ Cannot participate due to knee problems

Question 2

Reduced training volume

To what extent have you reduced you training volume due knee problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

Reduced performance

To what extent have knee problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

Pain

To what extent have you experienced knee pain related to your sport during the past week?

- ☐ No pain
- ☐ Mild pain
- ☐ Moderate pain
- ☐ Severe pain

Figure 9. The OSTRC Overuse Injury Questionnaire. While questions are shown for the knee, the questionnaire is intended to be applicable to any anatomical area

One of the key features of the method is that the anatomical areas of interest need to be established a priori, and the 4 questions are repeated for each area. As shown in Figure 9, there is a brief introduction to each area containing a relevant definition of a "problem" for that area.

The questionnaire was initially developed and tested using three common areas of overuse injury; the shoulder, the knee and the lower back (Bahr, 2009; Cook & Finch, 2011). We also included questions on the anterior thigh for the cyclists and cross-country skiers, as this was of clinical interest. However, our intention was that the questionnaire could be applied to any anatomical area.

Procedures

Questionnaire administration

As the questionnaire is intended to be regularly administered to large groups of athletes, it was designed in an electronic format. In all projects this was done using online survey software (Questback v. 9692, Questback AS, Oslo, Norway). The program automatically sent emails containing a link to the questionnaire to all athletes each Sunday. The questionnaire format was optimized to the device upon which it was opened, such that it could easily be completed using a smartphone, tablet or personal computer. If the link was not opened within three days, a reminder email was automatically sent to the athlete containing a new link.

Data management

Each week the questionnaire responses were exported from the survey software into a custom-made Microsoft Excel database (Microsoft Excel 2010, Microsoft Corporation, Redmond, USA) stored on a secure server at OSTRC. Data management procedures were approved by the Norwegian Data Inspectorate.

Classification of reported problems

At the conclusion of the study, all athletes were interviewed by a physiotherapist to confirm that injury information collected during the study was correct. Injuries that were associated with a specific, identifiable event were classified as acute injuries, and all others were classified as overuse injuries. If an acute injury had been sustained in the knee, shoulder, lower back or anterior thigh, data corresponding to these injuries that were obtained through the overuse injury questionnaires were separated in the database.

Outcome measures

An athlete was considered to have an *overuse problem* in a particular anatomical area if they reported anything but the lowest response to all four questions for that area. If they reported a moderate or severe reduction in training volume, a moderate or severe reduction in performance or a complete inability to participate (i.e. if they selected option 3, 4 or 5 in either Question 2 or Question 3), they were classified as having a *substantial overuse problem*.

We calculated the number of cases of overuse problems and of substantial overuse problems reported at any stage throughout the study for each anatomical area. This measure was expressed as an absolute number and as a percentage of athletes (*cumulative incidence*). Recurrent overuse problems at the same location were treated as a single case (Finch & Cook, 2013).

Prevalence measures

Each week the *prevalence of overuse problems* and the *prevalence of substantial overuse problems* were calculated for each anatomical area by dividing the number of cases by the number of questionnaire respondents. These measures were monitored over the course of the study and at its conclusion they were expressed as an average prevalence, together with a 95% confidence interval.

Severity measures

Every week, a *severity score* was calculated for each anatomical area for all athletes, based on their questionnaire responses. This was done by allocating all response options a numerical value from 0 to 25, and summing the responses to each of the four questions to give a score from 0 to 100. The values for intermediate responses were chosen in order to maintain as even a distribution from 0 to 25 as possible while still using whole numbers. Therefore, questions 1 and 4 were scored 0-8-17-25, and questions 2 and 3 were scored 0-6-13-19-25.

The severity score was used in a number of ways. First, it was plotted and used to monitor each athlete's overuse problems over the course of the project. Second, the *average severity score* was calculated for each anatomical area by averaging the score of all athletes that reported a problem each week. Finally, the *cumulative severity score* was calculated for each athlete by adding their scores over the course of the project. In Paper II, this was used as a basis for comparing the relative impact of overuse problems in each sporting group for each anatomical area.

Comparison to standard methods

In order to test the face validity of the new method, its results were compared to those of standard surveillance methods which were conducted in parallel over the course of the 13-week study. In the team sports, time-loss injuries were registered by the coach or physiotherapist during scheduled training sessions, according to the methods described in the F-MARC consensus statement (Fuller et al., 2006). For the individual sports, we employed methods similar to those described by Nilstad et al. (2014), whereby an extra question was added into their weekly questionnaires that asked whether they had experienced any form of physical complaint that prevented them from being fully able to train or compete in their sport. Athletes that answered 'yes' to this question were contacted by a researcher, and injuries that satisfied a time-loss injury definition were registered. The extra question was added to the end of the questionnaire, after the specific questions on knee, lower back and shoulder problems had been answered. It was stated clearly that they should report any problem, regardless of whether or not they had already reported the same one in the previous questions.

Overuse injuries located in the shoulder, lower back and knee were used as the basis for comparison of the two surveillance methods.

Risk factors for shoulder injuries in handball

Shoulder testing

We visited each team in the Postenliga in the four weeks prior to the season. All players were asked to complete a baseline questionnaire and were then subjected to a series of tests performed in random order. Tests included measurement of glenohumeral joint internal and external range of motion, measurement of isometric internal rotation, external rotation and abduction strength, and an assessment of scapular dyskinesis.

Baseline questionnaire

Information on players' shoulder injury history and status at the time of testing was collected using a modified version of the Fahlström questionnaire previously used in studies of elite handball players (Appendix III) (Myklebust et al., 2013). Each player was also asked whether they had ever undergone shoulder surgery.

Range of motion and isometric strength measurement

We used a digital inclinometer attached to a 30 cm Perspex ruler to measure glenohumeral joint range of motion (Acumar digital inclinometer, Lafayette Instrument, Lafayette Indiana, USA), and a digital handheld dynamometer to measure isometric shoulder strength (MicroFET, Hoggan Health Industries, Salt Lake City, Utah, USA). All measurements were performed with the player in supine, except abduction strength which was measured in standing (Figure 10). A detailed description of the test procedures is included in Appendix IV.

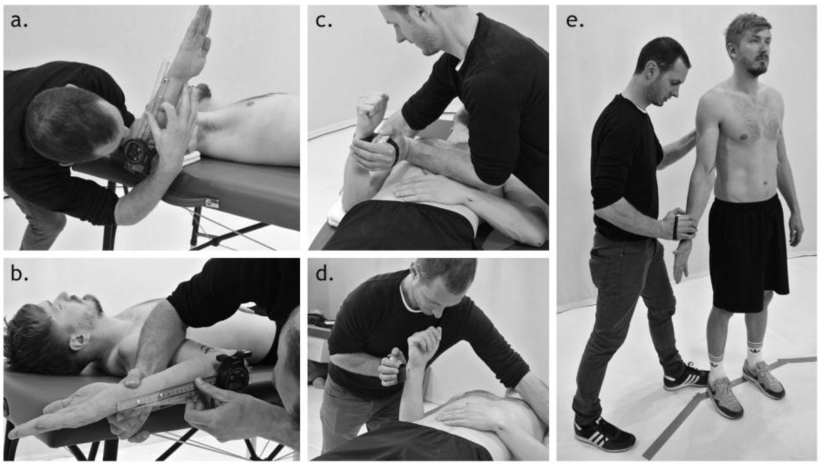

Figure 10. Measurement positions for (a) internal rotation range of motion, (b) external rotation range of motion, (c) internal rotation strength, (d) external rotation strength, and (e) abduction strength

All strength and range of motion measures were performed by one of two different physiotherapists, each of whom tested six teams. Their inter-rater reliability was tested in a pilot study, in which 38 shoulders were tested in a random order by both physiotherapists, who were blinded to the results of each other. The intra-rater reliability was assessed using the two measurements made during actual player testing.

Scapular dyskinesis assessment

A physiotherapist observed players perform five repetitions of flexion and abduction while holding a 5 kg weight. Each shoulder was rated as having normal scapular control, slight scapular dyskinesis or obvious dyskinesis, according to the methods proposed by McClure et al. (2009). All assessments were performed by the same physiotherapist, who made their rating based on live observation and, if necessary, inspection of recordings made by a video camera situated 3 m behind the player (Figure 11).

Figure 11. Assessment of scapular dyskinesis

Intra-rater reliability was assessed using 30 anonymised videos viewed in a randomised order and rated by the tester on two occasions separated by 1 week.

Registration of shoulder problems

During the entire regular season (30 weeks), problems in players' dominant and non-dominant shoulders were registered using the OSTRC Overuse Injury Questionnaire. While data collection procedures were largely similar to those used in Papers I and II, certain changes were made. First, the questionnaire was administered every second week rather than weekly, and two reminder emails were sent to non-responders; one after three days and another after seven days. Second, four questions on handball exposure were added to the end of the questionnaire, including the number of hours of handball training, weight training and alternative training (e.g. running and cycling), and the number of minutes of match play that the player had performed over the previous 14-day period. Finally, no attempt was made to classify shoulder problems reported by players as acute and overuse injuries.

Modification of the method to capture all health problems

As the new method was originally designed to record overuse problems in pre-defined anatomical areas, it is best suited for use in studies of relatively homogeneous groups of athletes who experience similar types of injuries. In studies of heterogeneous groups of athletes who are likely to sustain many different types of injuries, a different approach was needed.

The OSTRC Questionnaire on Health Problems

In Paper IV, the new method was modified such that it could register all types of health problems, including overuse injuries, acute injuries and illnesses. This involved the creation of a new electronic questionnaire called the Oslo Sports Trauma Research Center Questionnaire on Health Problems (Appendix V).

The questionnaire starts with four questions based on the OSTRC Overuse Injury Questionnaire (Figure 12). However, instead of using terms specific to an anatomical area, such as "knee problems," the broader phrase "illness, injury or other health complaint" is used. Similarly, in question 4, "pain" is replaced with "symptoms."

Oslo Sports Trauma Research Center Questionnaire on Health Problems

Please answer all questions regardless of whether or not you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

Question 1

Participation in normal training & competition

Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past week?

- ☐ Full participation without health problems
- ☐ Full participation, but with injury/illness
- ☐ Reduced participation due to injury/illness
- ☐ Cannot participate due to injury/illness

Question 2

Reduced training volume

To what extent have you reduced you training volume due to injury, illness or other health problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

Reduced performance

To what extent has injury, illness or other health problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

Symptoms

To what extent have you experienced symptoms/health complaints during the past week?

- ☐ No symptoms/health complaints
- ☐ To a mild extent
- ☐ To a moderate extent
- ☐ To a severe extent

Figure 12. The 4 key questions at the start of the OSTRC Questionnaire on Health Problems

In addition, the length of the questionnaire varied depending on the information provided by the athlete (Figure 13). If no problems were registered in any questions (full participation without problems/no training reduction/no performance reduction/no symptoms), the questionnaire was finished. However, if the athlete reported anything other than the minimum value in any of the four key questions, the questionnaire continued by asking the athlete to define whether the problem they referred to was an illness or an injury. In the case of an injury, they were asked to register its anatomical location, and in the case of an illness, they were asked to select the major symptoms they had experienced. For all types of problems, the number of days of complete time loss, defined as the total inability to train or compete, was also registered. Athletes were also asked whether or not the problem had been reported previously, whether the problem was already being treated (and by whom) and whether they had any further comments for their

Olympic medical team. This last question was included as the method was also intended to improve communication between elite athletes and their responsible medical personnel.

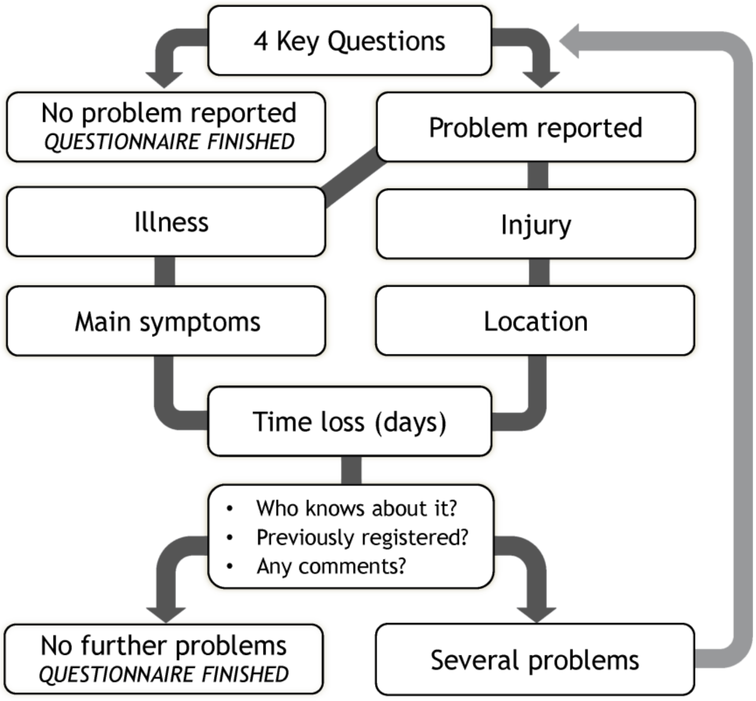

Figure 13. Diagram of questionnaire logic showing how the length of the questionnaire varied according to the number of health problems the athlete reported. Up to four health problems could be reported per week.

Procedures

While data collection and management procedures were similar to the first two projects, Project 3 involved two additional steps of reporting. First, a weekly summary report of athletes' questionnaire responses was sent to relevant medical staff of the Norwegian Olympic team. Team doctors and physiotherapists were then asked to return a monthly report classifying the type and diagnosis of each health problem reported by their athletes. In this report, injuries were coded using the Orchard Sports Injury Classification System (OSICS), V.10 (Rae & Orchard, 2007), and illnesses were coded using the International Classification of Primary Care, V.2 (ICPC-2) (World Health Organization, 2003).

Statistics

Data were analysed using either SPSS (SPSS versions 18-21, IBM Corporation, New York, USA) or Stata statistical software (STATA V.12.0, StataCorp LP, Texas, USA). In all papers, 95% confidence intervals were calculated for parameter estimates, and the two-tailed alpha level was set to 0.05 for all statistical tests.

Paper I

We analysed 1074 complete questionnaire responses to determine the internal consistency of the OSTRC Overuse Injury Questionnaire (Cronbach's α), and performed a factor analysis using a principle component analysis extraction method. The component matrix was assessed in order to determine whether it would be necessary to weight the questions' contribution to the injury severity score. If the factor loading of each question varied by less than 10%, this was taken as a sign that weighting the responses would be of little value (Streiner & Norman, 2008).

In order to assess the potential consequences of administering the questionnaire less frequently, we recalculated all outcome measures using only information from every second questionnaire and every fourth questionnaire. Outcome measures were also recalculated after removing the first questionnaire, and a related-samples Wilcoxon paired rank test was used to analyse differences between the first and second weeks in the prevalence of problems reported in each anatomical area in the five different sports.

Paper II

Univariate and multivariable logistic regression analyses were performed to assess whether baseline variables (sport, gender, age and years of sports participation) were associated with missing follow-up data. We also performed logistic regression analyses to evaluate if outcome data at specific follow-up points were related to missing data at the next follow-up point.

Based on these analyses, we concluded that missing data were of the type "missing at random" (van Buuren, 2012), and multiple imputation could be used to estimate missing data points.

Multiple imputation was performed using a predictive mean matching approach with a maximum of 20 iterations. This led to pooled data from five imputed datasets, which were used for the analysis of between-group differences. We also performed a sensitivity analysis comparing results obtained using the imputed dataset with those obtained using complete cases only. There were no differences in results, which supported our conclusion that missing data were "missing at random."

Differences over time in the prevalence of overuse problems and of substantial overuse problems between the five different sports were assessed using generalized estimating equations. A binary logistic model was used with an exchangeable covariance matrix. Subject age, gender, years of sports participation, height, and weight were included in the multivariable models, as univariate analyses of each of these factors revealed a possible association with the various injury outcomes over time ($p<0.2$).

The same method was also used to assess the effect of demographic variables on the risk of developing overuse problems and substantial overuse problems in each anatomical area. In this case, the multivariable logistic regression models were adjusted for sporting group.

Paper III

The reliability of the range of motion and strength tests was assessed by calculating the intraclass correlation coefficient using a two-way mixed model (absolute agreement) for inter-rater reliability and a two-way random model (absolute agreement) for intra-rater reliability (Cools et al., 2014). The intra-rater reliability of scapular dyskinesis testing was assessed using the Spearman rank-order correlation coefficient.

To analyse differences between dominant and non-dominant shoulders' strength and range of motion, we used paired-sample t-tests or Wilcoxon's rank-sum tests, depending on whether or not data were normally distributed.

We used the same methods to analyse missing data as described for Paper II. While no systematic differences between responders and non-responders were identified, we chose not to perform multiple imputation due to the amount of missing data. Instead, we excluded all players with less than 4 questionnaire responses ($n=42$) from risk factor analyses due to a lack of data, and created a summary outcome measure for all remaining players ($n=164$) by dividing their dominant shoulder's cumulative severity score by their number of questionnaire responses.

This score was heavily positive-skewed, which prevented us from using a linear regression model as neither the residuals nor the log-transformed residuals were normally distributed. Therefore, we dichotomized the outcome and used logistic regression, classifying all players with a score of 40 or more as injured. This cutoff point was selected as it corresponds to the player having substantial shoulder problems throughout the season, and because a Receiver Operator Characteristic curve analysis identified 40 as the value with the best predictive ability to identify significant risk factors.

To analyse risk factors, multivariable logistic regression models were constructed with demographic variables possibly associated to shoulder injury ($p<0.2$) added to each model using a forward selection procedure. Variables were kept in the model if adding them caused a change in the beta-coefficient of at least 10%.

Prior to performing risk factor analyses, we assessed the need to adjust for clustering. To do this, we performed a mixed model analysis with subjects clustered in teams. As adding a random intercept to the model at the team level did not change the -2 log likelihood and the variance was estimated to be zero, we concluded there was no need to adjust for clustering (Twisk, 2006).

Paper IV

We assessed the psychometric properties of the OSTRC Questionnaire on Health Problems and performed data simulations of different administration frequencies using the same techniques described for the OSTRC Overuse Injury Questionnaire in Paper I.

In order to analyse differences in the various prevalence measures between subgroups of athletes, Kruscal-Wallis non-parametric analysis of variance (ANOVA) tests were applied.

Linear regression analysis adjusted for repeated measures were used to analyse differences in the duration, cumulative severity and average weekly severity scores between different types of health problems, as well as between diagnosed and undiagnosed health problems.

Results and Discussion

Comparison of the new method and standard surveillance methods (Paper I)

The new method led to the identification of 419 overuse problems in the shoulder, lower back and knee, affecting 236 athletes (75% of the cohort). In 17% of cases only mild pain was reported, with no associated reductions in sport participation or performance. However, 34% of cases were classified as substantial overuse problems as they led to moderate or severe reductions in sports participation or performance, or a total inability to participate.

At any given point during the course of the study, an average of 39% of the cohort were suffering from overuse problems in in the knee, lower back or shoulder (CI: 34% to 44%), and 13% had substantial problems (CI: 12% to 15%). The average duration of problems was 5 weeks (CI: 4 to 5 weeks).

In contrast, standard surveillance methods identified a total of 40 overuse injuries located in the shoulder, lower back or knee. These were distributed among 33 athletes (11% of the cohort). Most were of minimal severity, with 28 cases leading to less than 3 days of time loss; 9 cases were mild (4-7 days), 15 were moderate (8-28 days) and 8 were severe (>28 days).

The two surveillance methods, therefore, painted a vastly different picture of the extent and severity of overuse injuries among the athletes in the study. As each method used different injury definitions and outcome measures, they cannot be directly compared. However, the inadequacy of standard surveillance methods to capture the true magnitude of overuse injuries was clearly documented. In contrast, the new method was shown to be a viable alternative that led to the capture of over ten times the number of cases.

The response rate to the weekly questionnaires was 93%, which demonstrating the feasibility of the study design. This was important to establish, as the data collection procedures were largely untested in sports medicine research.

Properties of the OSTRC Overuse Injury Questionnaire

The questionnaire had high internal consistency, with a Cronbach's α of 0.91. This was not improved any further by removing items. The factor weighting ranged from 0.86 to 0.91 for the four questions, suggesting that there is a little statistical justification for weighting items differently in the calculation of the severity score.

Sampling less frequently led to fewer cases being identified; however, average prevalence and average severity measures were not affected. The prevalence of overuse problems was highest in the first questionnaire for all anatomical areas ($p<0.01$ vs the second questionnaire), and reanalysis of the dataset after removing the first questionnaire led to a 14% reduction in the number of problems identified without affecting the average prevalence or average severity score.

Validity of the OSTRC Overuse Injury Questionnaire

The validity of an instrument such as the OSTRC Overuse Injury Questionnaire refers to the degree to which it measures the construct it purports to measure (Mokkink et al., 2010). Rather than being determined "once and for all" by any single finding, validity is established gradually through the accumulation of different types of evidence, such as face validity, content validity, criterion validity, and construct validity (Streiner & Norman, 2008; Mokkink et al., 2010; Davidson & Keating, 2014). Other measurement properties, such as reliability and responsiveness, also affect an instrument's overall validity (Mokkink et al., 2010).

Face validity refers to whether, "on the face of it," an instrument appears to be assessing the desired qualities (Streiner & Norman, 2008; Mokkink et al., 2010). This was perhaps the main form of validity established in Paper I, simply because repeated administration of the OSTRC Overuse Injury Questionnaire appeared to work well to record overuse injuries, especially when contrasted with standard surveillance methods.

Content validity refers to the degree to which the content of an instrument adequately reflects the construct of interest (Davidson & Keating, 2014). This is a subjective judgment which should be made by users of the instrument and experts in the field (Streiner & Norman, 2008; Terwee et al., 2007). In order to establish the content validity of the questionnaire, we included athletes, coaches, clinicians and sports injury epidemiologists in its development. In particular, all stakeholders were involved in the determination of which domains were relevant and adequate to record overuse injuries in sport.

Evidence of face and content validity was also provided in an independent validation of a Swedish translation of the questionnaire (Ekman et al., 2013). In this study, the questionnaire's content was reviewed by an expert panel and then used to register overuse injuries among a group of 43 athletes from 4 sports over 10 weeks. At the conclusion of the 10 weeks, athletes reported that the questions were "well formulated, easy to understand and relevant." The authors concluded that the content validity of the questionnaire appeared to be high.

Criterion validity refers to the degree to which the scores of an instrument are an adequate reflection of an accepted "gold standard" (Mokkink et al., 2010). This is the most empirical form of validity which is tested using correlational statistics. However, in order to establish criterion validity, a "gold standard" must exist. This is problematic for recording overuse injuries as there is currently no surveillance method considered valid for recording their occurrence or severity (Bahr, 2009). Similarly, validation against laboratory or clinical diagnostic tests is also difficult as specific and sensitive diagnostic tests are lacking for many types of overuse injuries (Roos & Marshall). For example, there is often a poor correlation between symptoms of overuse injury and the results of diagnostic imaging; pathological changes often exist on imaging in the absence of pain (Connor et al., 2003; Jost et al., 2005; Kaneoka et al., 2007; Fredericson et al., 2009; Hurd et al., 2011a; Soder et al., 2012; Kornaat & Van de Velde, 2014; Visnes et al., 2014), and pain may exist in the absence of imaging findings (Lian et al., 1996; Malliaras & Cook, 2006; Visnes et al., 2014). For these reasons, we made no attempt to establish criterion validity of the questionnaire.

Construct validity refers to the extent to which an instrument measures the intended construct, and the inferences that can therefore be made from the scores (Davidson & Keating, 2014). It is mainly established through the confirmation of assumptions about the relationship the instrument's scores should have with those of other instruments, or about differences in scores between relevant groups. For example, in Paper I the confirmed assumption was that the new method would reveal a far greater number of overuse problems than standard surveillance methods. As this was one of the main reasons why the new method was developed, a failure to do so would have reflected badly on the construct validity of the questionnaire.

Another, more empirical aspect of the construct validity of an instrument is *internal consistency,* which refers to the degree to which its individual items correlate with each other and with the overall score (Streiner & Norman, 2008). We found the internal consistency of the OSTRC Overuse Injury Questionnaire to be high, indicating that all items measure the same construct.

Reliability refers to the degree to which measurements are free from measurement error (Mokkink et al., 2010). It is related to test validity, as an instrument with poor reliability cannot be considered valid (Streiner & Norman, 2008). There are several forms of reliability, including inter-rater, intra-rater, and test-retest reliability (Mokkink et al., 2010). As the questionnaire is delivered electronically, inter-rater and intra-rater reliability are not relevant. However, test-retest reliability should be established. The challenge in doing so is to determine the optimal interval in which this should be tested. If the interval is too short, athletes would be likely to recall their previous responses. If it is too long, their real injury status is likely to have changed.

Finally, the *responsiveness* of an instrument refers to its ability to detect change over time in the construct to be measured (Mokkink et al., 2010). The challenges in establishing responsiveness are much the same as for criterion validity in that it is necessary to have a gold standard of change in the construct that the instrument can be measured against. As this is lacking for overuse injuries, no attempt was made to determine the responsiveness of the questionnaire.

The prevalence and impact of overuse injuries in five sports (Paper II)

Table 2 shows the prevalence of all overuse problems and of substantial overuse problems in each anatomical area for each of the five sports involved in the first project.

Table 2. Average prevalence of all overuse problems and of substantial problems, % (95% CI)

	XC Skiing	Cycling	Floorball	Volleyball	Handball
All overuse problems					
Shoulder	1 (0 to 3)	7 (4 to 10)	15 (9 to 20)	16 (14 to 19)	22 (16 to 27)
Lower back	5 (2 to 9)	16 (12 to 20)	29 (25 to 33)	14 (11 to 16)	12 (8 to 16)
Knee	8 (5 to 11)	23 (17 to 28)	27 (24 to 31)	36 (32 to 39)	20 (16 to 25)
Anterior thigh	12 (8 to 15)	8 (7 to 9)			
Substantial overuse problems					
Shoulder	1 (0 to 1)	1 (0 to 1)	1 (0 to 2)	5 (4 to 6)	6 (4 to 8)
Lower back	1 (1 to 2)	6 (4 to 7)	3 (1 to 4)	1 (1 to 2)	2 (1 to 3)
Knee	1 (0 to 2)	8 (7 to 9)	4 (2 to 6)	15 (13 to 17)	8 (6 to 10)
Thigh	7 (5 to 8)	4 (3 to 5)			

Substantial overuse problem: causing moderate/severe reductions in training volume or sports performance, or complete inability to participate in training or competition. XC = Cross to country.

Although a thorough discussion of each finding is beyond the scope of this dissertation, in most cases our results confirmed expectations, based on our clinical experience as well as previous epidemiological studies and review articles. In this regard, the findings of this paper strengthen the construct validity of the questionnaire.

For example, as shown in Table 1, the area with the highest average prevalence of overuse problems and of substantial overuse problems was the knee in volleyball. This area clearly has the highest impact on athletes of all the areas we recorded using the new method to date (Figure 14). This supports the results of previous cross-sectional studies of volleyball players which have documented a high prevalence of overuse knee injuries in comparison to other sports (Lian et al., 2005; Zwerver et al., 2011). However, ours are the first prospective data illustrating this.

Similarly, previous studies have shown that overuse knee and lower back injuries are common in road cycling (Clarsen et al., 2010), and shoulder injuries are common in volleyball (Wang & Cochrane, 2001; Bahr & Reeser, 2003; Reeser et al., 2010) and handball (Gohlke et al., 1993; Myklebust et al., 2013). Our data support these findings.

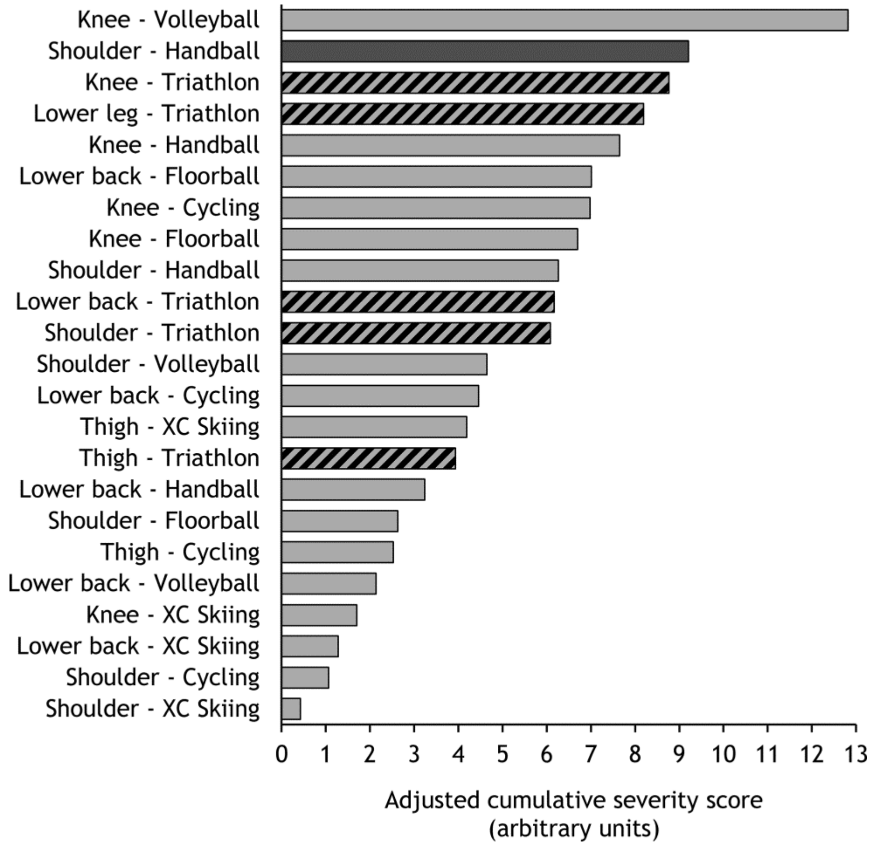

Figure 14. Relative impact of overuse problems between different anatomical areas and different sporting groups, shown as the cumulative severity score adjusted for the number of questionnaire responses. Data are from Paper II (light grey bars), Paper III (dark grey bar) & Andersen et al., 2013 (striped bars)

One result that contrasted with prior research, however, was the low prevalence and impact of lower back problems in cross-country skiing. Lower back pain has previously been reported to be particularly common among high-level cross-country skiers (Orava et al., 1985; Eriksson et al., 1996; Bahr et al., 2004; Bergstrom et al., 2004; Alricsson & Werner, 2005; Alricsson & Werner, 2006). However, a majority of previous studies have failed to assess the impact of back pain on skiing participation and performance, which we found to be minimal in our sample (Figure 14).

One of the main limitations to the study is that because we used a convenience sample, the external validity of the results may vary between sports. For example, the cohort of cyclists included almost every elite-level cyclist in Norway, whereas the floorball and handball players came from a single club. Furthermore, as the duration of surveillance was only 13 weeks, the study does not account for potential variations in injury prevalence over the entire season.

However, as little information exists on the extent of overuse injuries in any of the five sports, particularly from prospective studies, this paper contains new information that may be valuable in guiding future injury prevention research. For example, continued focus on the prevention of knee injuries in volleyball is justified, whereas research towards on prevention of lower back pain in cross-country skiing is not.

Comparisons of the risk of overuse problems between each sport may be of limited interest to most readers of the paper. However, we chose to include these analyses to illustrate how missing data can be handled and how between-group comparisons of repeated measures can be made, and because they reinforce the construct validity of the new method. These analyses also highlight the potential confounding effect of differences in demographic characteristics between groups.

Risk factors for shoulder injuries in handball (Paper III)

The extent of the problem

During the course of the season, 108 players (52% of the cohort) experienced problems in their throwing shoulder. Fifty players (24% of the cohort) reported substantial shoulder problems. The average prevalence of shoulder problems was 28% (CI: 25% to 31%) and the average prevalence of substantial shoulder problems was 12% (CI: 11% to 13%).

These data are among the highest we have measured to date using the new surveillance method, which can be illustrated by comparing the cumulative severity score to those reported in Paper II (Figure 14). Clearly, shoulder injuries in handball warrant preventative efforts.

Risk factor analyses

Our results are based on 164 players who returned 4 or more questionnaires throughout the season. As players were excluded if they had pain during testing, between 147 and 163 athletes were included in each analysis. Fifteen players had an average severity score above 40 throughout the season and were classified in the injury group in risk factor analyses.

Demographic risk factors

A history of shoulder surgery (OR: 8.3, CI: 1.3 to 51.4, p=0.02) and playing in a back position (OR: 16.4, CI: 2.0 to 132.3, p<0.01) were significantly associated with shoulder injury. No associations were identified between injury and age, height, body mass, years of handball participation, years of participation at an elite level or their team.

Scapular dyskinesis

A total of 32 players were rated as having slight scapular dyskinesis in their dominant shoulders and 16 players (7%) were rated as having obvious scapular dyskinesis. The relationship between slight scapular dyskinesis and injury was not statistically significant (OR: 3.5, CI: 0.8-14.5, p=0.09). However, obvious dyskinesis was significantly associated with shoulder injury (OR: 8.4, CI: 1.5-48.1, p=0.02).

To our knowledge this is the first study to demonstrate a significant relationship between scapular dyskinesis and shoulder injury among overhead throwing athletes. While it has previously been shown to be common among athletes from a variety of overhead sports, such as baseball, swimming and tennis (Myers et al., 2005; Oyama et al., 2008; Madsen et al., 2011), evidence of an association has been lacking as it is common among symptom-free athletes as well as those with pain (Kibler et al., 2009; Tate et al., 2009; Myers et al., 2013; Struyf et al., 2014). We may have been able to demonstrate a relationship due to a sufficient number of players being included in the study, and because the outcome measure was sufficiently sensitive to detect those with the greatest amount of shoulder problems.

Range of motion

The range of motion of players' dominant and non-dominant shoulder was significantly different, with dominant shoulders having reduced internal rotation (mean difference: 4°, CI: 3° to 5°, $p<0.01$), increased external rotation (mean difference: 6°, CI: 5° to 8°, $p<0.01$) and increased total rotational motion (mean difference: 3°, CI: 1° to 4°, $p<0.01$) compared to non-dominant shoulders (Figure 15).

A similar pattern has been demonstrated among athletes from a range of overhead sports (Ellenbecker et al., 1996; Ellenbecker et al., 2002; Trakis et al., 2008; Reeser et al., 2010; Wilk et al., 2011; Almeida et al., 2013; Manske et al., 2013; Myklebust et al., 2013). While this is generally regarded to be a normal adaptation to repeated throwing (Kibler et al., 2013a), several studies have linked differences in range of motion between dominant and non-dominant shoulders to injury (Myers et al., 2006; Ruotolo et al., 2006; Shanley et al., 2011; Wilk et al., 2011; Almeida et al., 2013).

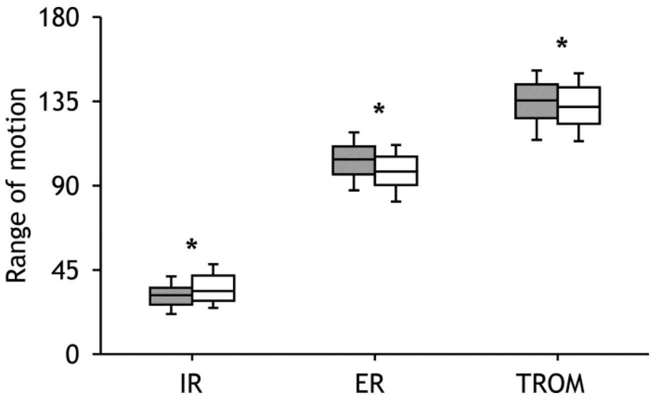

*Figure 15. Range of motion differences between dominant shoulders (grey boxes) and non-dominant shoulders (white boxes) ER, external rotation; IR, internal rotation; TROM, total rotational motion; *p<0.05*

In the current study, the differences between shoulders were smaller than those demonstrated in other sports, particularly baseball pitchers (Manske et al., 2013), and we were unable to identify any association between these differences and injury. In contrast, a significant association was identified between the (absolute) range of total rotational motion in the dominant shoulder and injury (OR: 0.77 per 5° increase, CI: 0.56-0.995, $p<0.05$).

Isometric strength

Players' dominant shoulders were significantly weaker in external rotation (mean difference: 0.09 Nm/kg, CI: 0.04 to 0.13, $p<0.01$) and stronger in abduction (mean difference: 0.07 Nm/kg, CI: 0.02 to 0.12, $p<0.01$) compared to their non-dominant shoulders. The ratio of external to internal rotation strength was lower for dominant shoulders (mean difference: 4%, CI: 2% to 6%, $p<0.01$) (Figure 16).

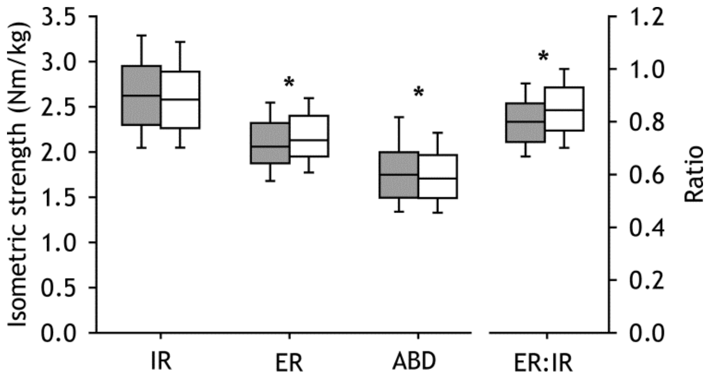

*Figure 16. Isometric strength differences between dominant shoulders (grey boxes) and non-dominant shoulders (white boxes) ABD, abduction; ER, external rotation; IR, internal rotation; *p<0.05*

A significant association was identified between isometric external rotation weakness and injury (OR: 0.71 per 10 Nm change, CI: 0.44 to 0.99, $p<0.05$). There was no association between internal rotation strength and injury. However, non-significant trends in the data suggest that lower external to internal rotation strength ratios (OR: 0.75 per 5% change, CI: 0.45 to 1.08, $p=0.13$) and abduction weakness (OR: 0.81 per 10 Nm change, CI: 0.61 to 1.03, $p=0.08$) may also be noteworthy risk factors. Similar findings have been reported in studies of baseball pitchers, where isometric external rotation, abduction and external to internal rotation strength ratios have been associated with shoulder injury (Trakis et al., 2008; Byram et al., 2010; Tyler et al., 2014).

Limitations of the study

One of the main limitations of this study is that a causative relationship cannot be assumed between risk factors and shoulder injury. Traditionally, risk factor studies (of acute injuries) exclude injured players at baseline and only record new injuries. As risk factors are shown to exist before the onset of injury, a causative relationship can be assumed. However, a majority of the shoulder injuries recorded during the study were chronic problems that already existed at baseline. Excluding these cases would have severely biased our results.

This is likely to be a problem for all risk factor studies of overuse injuries among adult, elite athletes. In these cases, causality may be established by proxy if studies are followed up with randomized controlled trials of risk factor modification. For example, if an intervention aimed at increasing shoulder external rotation strength could be shown to reduce the prevalence of shoulder injury, a causative relationship between external rotation strength and injury may be assumed.

The study is also limited by the selection of shoulder tests. For example, the validity of the strength tests may be questionable as they were static tests performed with the player in supine with their arm by their side. Obviously, this differs greatly from dynamic, overhead throwing. Similarly, scapular dyskinesis was assessed during simple, uniplanar movements, rather than during actual throwing. However, the test protocol was selected in order to maximize the reliability of measurements, which was good for both strength (ICC: 0.80 to 0.91) and scapular dyskinesis tests (Rs: 0.69 to 0.78).

For range of motion measures, the intra-rater reliability was very high (ICC: 0.98 to 0.99). While the inter-rater reliability was good for external rotation (ICC: 0.88), it was only moderate for internal rotation (ICC: 0.65). This may have increased the likelihood of type II error in risk factor analyses involving this measure.

Implications for injury prevention

Despite these limitations, our results provide sufficient evidence to recommend the development and testing of injury prevention programs for handball players that target glenohumeral joint range of motion, external rotation strength and scapular control.

One factor to consider in program development, however, is the potentially deleterious effect of excessive shoulder range of motion (Wilk et al., 2002). Although our results imply a linear relationship between shoulder stiffness and injury risk, Wilk et al. (2011) found that baseball pitchers with over 176° of total rotation were also at greater risk of injury. This suggests that the most flexible players should refrain from performing stretching exercises. However, this may be more of a problem for baseball pitchers, as the handball players in this study had, on average, approximately 40° less rotation than the values typically reported for pitchers (Manske et al., 2013), and no player had more than 171°.

Monitoring of health problems in the Norwegian Olympic team (Paper IV)

During the 40 weeks prior to the Olympic Games, athletes reported 617 health problems. Of these, 582 cases (94%) were followed up by medical staff and classified with an ICPC-2 or OSICS-10 code. The average weekly prevalence of health problems was 36% (CI: 34% to 38%), and an average of 15% of athletes reported substantial health problems each week (CI: 14% to 16%).

A total of 329 illnesses were reported by 106 athletes during the study (76% of the cohort). Of these, 198 cases were classified as substantial problems. The average prevalence of illness was 13% (CI: 12% to 14%) and the average prevalence of substantial illness was 6% (CI: 6% to 7%). A majority of illnesses affected the respiratory system (68% of cases) and the digestive system (16% of cases). The average duration of illnesses was 1.8 weeks (CI: 1.6 to 2.0 weeks).

A total of 288 injuries were reported by 115 athletes during the study (80% of the cohort). Of these, 202 cases were classified as overuse injuries, 60 as acute injuries and 26 were unclassified. One-hundred and twenty-two injuries were substantial problems, including 86 overuse injuries and 27 acute injuries (9 were unclassified). The average prevalence of overuse injury was 20% (CI: 18% to 21%) and the average prevalence of substantial overuse injury was 7% (CI: 6% to 8%). The average prevalence of acute injury was 4% (CI: 3% to 5%) and the average prevalence of substantial acute injury was 2% (CI: 2% to 3%). The average duration was 5 weeks for overuse injury (CI: 4 to 6 weeks) and 3 weeks for acute injury (CI: 2 to 4 weeks).

In order to assess the relative burden of the different types of health problems, the cumulative severity of all cases was compared. Overuse injuries represented the greatest burden on athletes' participation and performance (49%), followed by illness (36%) and acute injury (13%).

Properties of the OSTRC Questionnaire on Health Problems

The psychometric properties of the OSTRC Questionnaire on Health Problems were similar to the OSTRC Overuse injury Questionnaire. The internal consistency was high regardless of the type of health problem recorded (Cronbach's α 0.94 to 0.96), and this was not improved by removing any questions. The factor weighting was relatively even between questions, ranging from 0.87 to 0.94. These findings suggest that the four questions measure the same construct (i.e. "health problems"), and that the questionnaire properties are similar when it is used to record both injuries and illnesses. There was little statistical justification to weight response options differently when calculating the severity score.

Also, similar to the OSTRC Overuse Injury Questionnaire, our data simulations suggested that prevalence measures would be largely unaffected if the questionnaire were to be administered less frequently, although fewer cases would be identified.

Health monitoring as secondary prevention

In Paper IV, our intention was not only to develop a method that could be used to collect data on athletes' health problems for research purposes, but also one that could be used as a practical tool to improve their medical coverage. Many elite athletes, particularly those from individual sports, spend much time travelling without medical coverage, and they often live across a broad geographical area and relate to several medical personnel simultaneously (Edouard et al., 2014). These factors can contribute to sub-optimal management of health problems, particularly in the early phase of overuse injury. In this case, the early identification of problems by a dedicated health team can be seen as secondary prevention, due to an earlier initiation of appropriate management strategies (Meeuwisse & Bahr, 2009).

Although we did not attempt to measure the effect of the weekly reports, it was our impression (as both project coordinators and members of the Olympic health team) that they were successful as a secondary prevention tool. However, there remains potential for improvement. Under the current approach it can take up to five days from when an athlete reports a problem until their medical team is notified of it. A greater degree of automation of the reporting system, with instantaneous alerts to medical staff when certain reporting criteria are met, may substantially improve its effectiveness.

Methodological considerations

Missing data

One of the main limitations of the new method is a reliance on a good response from athletes. Our response rates were 93% (Papers I & II), 63% (Paper III) and 80% (Paper IV). While these are all above average for academic surveys (Baruch, 1999), there are no criteria for what constitutes a "good" response rate in sports injury research, and our goal when planning the projects was to achieve over 80%.

A high response rate is desirable for a number of reasons. First, it increases the likelihood that data are internally valid (that is, that they are representative of the entire study sample). This is particularly the case when the response to questionnaires is influenced by factors such as subject demographics or injury status. For example, if athletes with no history of injury regarded the study as irrelevant to them and failed to respond to the questionnaires, the actual prevalence of injury would be overestimated.

If sufficient data on participants exists at baseline, the likelihood of this form of bias having occurred can be assessed. For example, in Papers II & III, multivariable regression analyses were performed to determine whether demographic variables or injury history were predictive of data completeness. As no associations were identified, we concluded that data were missing at random and therefore internally valid. However, this approach is far from certain, and the best way to ensure that data are truly representative is to maximize the response rate.

The amount of missing data also affects which statistical methods can be used. Ideally, longitudinal methods such as generalized estimating equations should be used to analyse repeated measurements, as these account for change over time (Twisk, 2006). However, one of the limitations of this analysis is that all subjects with any missing data are excluded. This is likely to lead to the exclusion of a large proportion of subjects in studies with many repeated measurements, reducing statistical power and increasing the likelihood of biased results.

One way of retaining subjects with missing data is to estimate their missing values using multiple imputation. However, multiple imputation methods can only be utilized if data are missing at random and if sufficient data exists (Sterne et al., 2009). There are no definitive criteria for the amount of data necessary, but as a general rule 70% of the total dataset should exist, and at least 50% of subjects should have complete data (M.W. Heymans, personal communication, 2013).

This prevented us from using multiple imputation and longitudinal analyses in Paper III, and further highlights the need for a good response rate.

We considered numerous factors in order to maximize the response rate. For example, the questionnaire was designed to be quick and easy to fill out, and poorly-responding athletes were routinely reminded to participate using automated emails and direct telephone contact. Where possible, individuals well-known in the relevant sporting milieu such as the national team doctor or physiotherapist were used to follow up poor responders and as the public "face" of the study. Additionally, in certain cohorts athletes who completed all questionnaires were eligible to win prizes. Perhaps the most important factor, however, was the extent to which athletes, coaches and medical staff could be convinced that there was a direct benefit for them if they participated in the project. In the first two projects (Papers I-III), this primarily involved repeated written and verbal reinforcement of the potential contribution that the study could make towards primary injury prevention in their sport. In the third project (Paper IV), an additional benefit for athletes was that participation in the study may have directly improved their medical support.

When electronic questionnaires are used, it is highly important that data are collected with appropriate tools. So far, all studies using the new method have distributed questionnaires through email-based online survey software. Although the actual questionnaire is completed in the internet browser, allowing it to be completed on a range of devices, our current approach is dependent on athletes actually opening the email. However, recent communication trends suggest that email may be rapidly being superseded by social media and mobile applications, particularly among young people (Duffy, 2011; Foo, 2011; Philipson, 2014). In order to maximize response rates, it is essential that methods of questionnaire administration are continually reassessed to reflect the changing nature of communication.

Outcome measures

In this dissertation we propose not only a new method of collecting injury data, but also new ways of expressing the extent and severity of overuse injuries in sport. Our suggestions are based on Bahr's recommendation that the extent of overuse injuries should be expressed using measures of prevalence rather than incidence (Bahr, 2009). However, prevalence is typically a cross-sectional measure and no standards exist for how it should be expressed in prospective studies involving repeated measures. Incorporation of the various domains measured by the questionnaire into a few number of easily communicable and meaningful outcomes proved to be a particular challenge.

Prevalence measures

In calculating our primary outcome measure, the prevalence of overuse problems, an athlete was classified as having an overuse injury if they recorded anything but the minimum value for any of the four key questions. This is consistent with the "all physical complaints" definition recommended in a majority of consensus statements (Fuller et al., 2006; Fuller et al., 2007; Pluim et al., 2009; Turner et al., 2012; Timpka et al., 2014a). As this is measured repeatedly throughout a project, changes in the prevalence of overuse problems can be monitored over time due to, for example, seasonal variation or the effect of a prevention intervention. In addition, the average prevalence of overuse problems gives an indication of the percentage of athletes experiencing overuse problems at any given point in time. However, this measure has several limitations. First, as the recording threshold is particularly low, some cases of "normal" soreness related to sports participation may be regarded as injury, leading to an overestimation of the true extent of the problem. Second, we have noticed that in all projects which have used the new method, there is a downward trend in the prevalence of all overuse problems. This may be explained by the "respondent fatigue" phenomenon (Ben-Nun, 2008), whereby athletes' reporting threshold, particularly for minor or chronic problems, increases over time. Finally, summarizing prevalence as an average measure is only meaningful if data are normally distributed, and doing so may lead to valuable information about prevalence trends being missed.

In order to filter out the most minor problems, we also reported the prevalence of substantial overuse problems, defined as overuse problems leading to moderate or severe reductions in training volume, moderate or severe performance limitation, or a complete inability to participate. Reporting this in parallel with the prevalence of all overuse problems better illustrates the full extent that a particular group may be affected by overuse injury. This is well demonstrated by lower back problems among floorball players and cyclists, reported in Paper II.

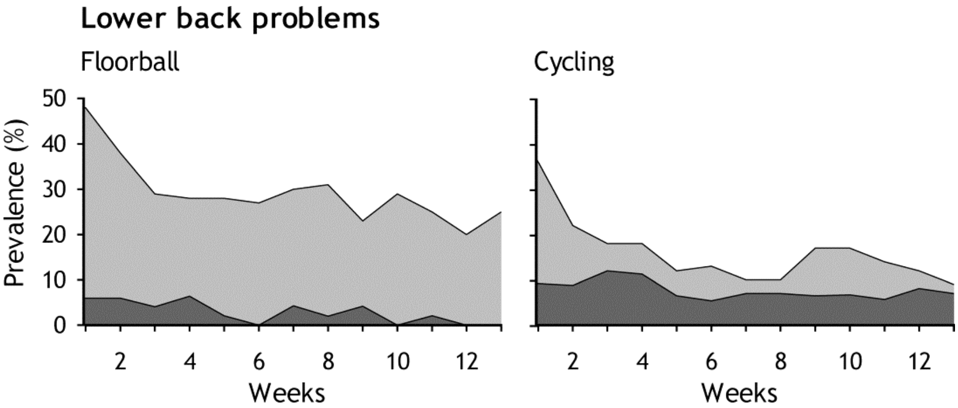

Figure 17. The prevalence of all overuse lower back problems (light area) and substantial overuse lower back problems (dark area) among floorball players and cyclists (Paper II)

As shown in Figure 17, if the outcome measure "all lower back problems" is considered in isolation, floorball players appear to be far more affected than cyclists, having an average prevalence of 29% (CI: 25% to 33%) compared to 16% (CI: 12% to 20%). However, the prevalence of substantial lower back problems among cyclists was double that of floorball players (6%, CI: 4% to 7% versus 3%, CI: 1% to 4%). This suggests that lower back problems in cycling, rather than floorball, may in fact be more deserving of research attention.

The prevalence of substantial problems also appears to be less affected by respondent fatigue, as there is no indication of a downward trend across cohorts and studies. Perhaps its main limitation, however, lies in the criteria used to define a substantial problem. These were selected post hoc during analysis of the data for Paper I, simply because they "made sense" to us. As such, the content validity of the classification has never been formally established with athletes.

Severity score

We converted athletes' questionnaire responses to a severity score ranging from 0-100 for a number of reasons. First, as it makes use of all the questionnaire data the impact of overuse injury (and other health problems) is better quantified. This enables monitoring of the progression of problems on an individual level (Figure 18), and provides a sensitive outcome measure for risk factor studies and prevention trials. It also allows for comparisons of the relative impact of health problems within and between athletes, and between different cohorts and studies.

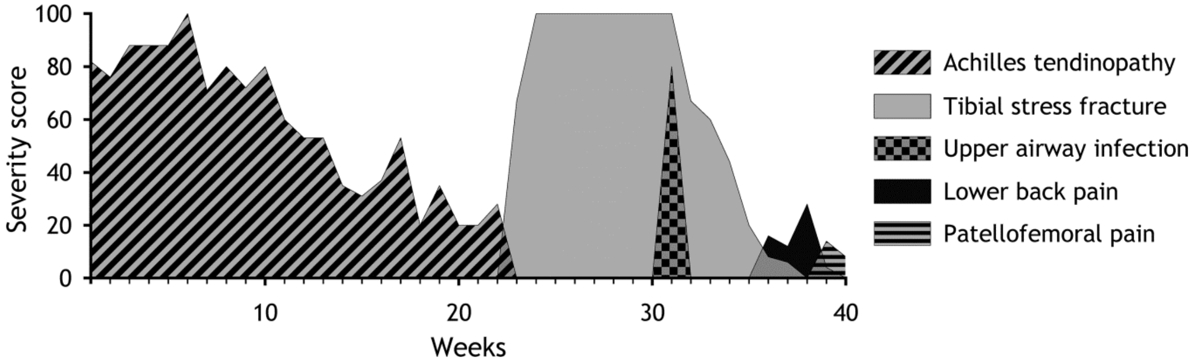

Figure 18. Example of the severity score being used to monitor the progression of several health problems over time. Data are from an actual athlete during their preparation for the Olympic Games.

However, there are several limitations to the severity score. First, in contrast to time-loss based severity measures used in standard surveillance methods, it is an arbitrary number with no inherent meaning to athletes or coaches. Second, the distribution of scores in a group of athletes is likely to be highly positive-skewed, as at any given time most athletes will be either be injury-free or experiencing mild problems. This makes summarising scores very challenging; the average score is not meaningful as the distribution is not normal, and if more than 50% of athletes are injury-free, the median score will be zero. Therefore, the validity of the severity score as a descriptive outcome measure is limited.

When the cumulative severity score is used to assess the total impact of overuse injury, such as in Figure 14, sports with a high prevalence of mild problems may be ranked higher than those with fewer, more serious problems. Again, comparison of lower back problems in floorball and cycling highlights this limitation. Although cyclists had double the prevalence of substantial problems, floorball had a higher cumulative severity score due to the large number of players who reported minor problems. This issue could potentially be solved by weighting the scoring system more heavily in favour of more severe problems.

Limited information can be collected from athletes

Another important limitation of the new surveillance method is that only a limited amount of information can be collected directly from athletes. As we did not expect them to be able to reliably report detailed diagnostic information, the OSTRC Overuse Injury Questionnaire and the OSTRC Questionnaire on Health Problems focus solely on the degree of symptoms experienced by athletes and the consequences on sports participation, training volume and performance. In order to gather diagnostic information and correctly classify injuries as acute or overuse, follow-up by trained medical staff is required.

The extent to which we were able to do this varied between the three projects. In the first project (Papers I & II), telephone interviews were conducted by physiotherapists with all athletes at the conclusion of the study. As this approach lacks physical assessment and may be limited by recall bias, no attempt was made to record diagnoses. However, we felt confident that injuries could be classified as acute or overuse using this approach, based on whether they could be linked to a specific identifiable injury event.

In the second project (Paper III) we did not attempt to diagnose or classify the reported shoulder problems. This is a substantial limitation of the study, and while our clinical experience suggests that a majority of shoulder problems experienced by handball players are related to overuse, a lack of separation of the injury types may have reduced our ability to identify risk factors for overuse injury.

In the third project (Paper IV), we were able to record a very high level of diagnostic detail for 93% of all reported problems, which is an obvious strength of the study. This was possible as Olympic team medical personnel, who followed athletes closely for the duration of the project, were involved in data collection. However, this approach may only be feasible in certain situations such as elite sports where athletes have consistent and intensive medical coverage.

Using medical staff to diagnose and/or classify injuries places an upper limit on the size of the cohort that can be followed using the new method, regardless of whether it is done prospectively or during a summary interview at the conclusion of the study. In studies of very large cohorts or with fewer resources, an alternative approach could be to add an extra question to the questionnaire asking athletes whether or not reported physical problems were caused by a specific, identifiable event. This approach would likely lead to some misclassification of sudden-onset overuse injuries as acute, but is nonetheless preferable to not attempting to classify injuries at all.

Conclusions

1. Standard injury surveillance methods are inadequate to measure overuse injuries in sport. We have proposed a new method which has good face, content and construct validity to record the full extent of overuse problems, and have demonstrated that it is feasible to apply the method successfully in studies of elite Norwegian athletes.

2. Overuse injuries are highly prevalent among elite athletes. We identified particular problem areas in a number of sports, such as the knee in volleyball and the shoulder in handball. Continued research focus toward the prevention of these problems is warranted.

3. Reduced glenohumeral joint range of motion, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among professional male handball players. These factors should be addressed in injury prevention programs.

4. The new method can be used to monitor not only overuse injuries, but also acute injuries and illnesses in large, heterogeneous groups of elite athletes. We used it to monitor Norwegian athletes preparing for the Olympic and Paralympic games, and showed that of the different types of health problems, overuse injuries had the greatest impact on sports participation and performance.

Future Perspectives

The new method seems to have been generally well-received by the field of sports injury prevention. It is currently being used by other research groups in a number of countries, and has been recommended in a recent consensus statement on methodology for epidemiological studies in athletics (Timpka et al., 2014a). Obviously, we regard this as positive, but it should be recognized that the validity and feasibility of the method has currently only been established in Norway and Sweden. The need for cross-cultural validation in other areas of the world should be emphasized.

As described in this dissertation, the new method has been used in surveillance studies of a number of different sporting groups, including cross-country skiers, road cyclists, triathletes, floorball, handball, and volleyball players, and the Norwegian Olympic and Paralympic team. However, these represent only a fraction of sports in which overuse injuries are a potential problem. Furthermore, although there has been some variation in the demographics of each cohort, our primary focus to date has been on adult, elite-level athletes and little is known about other groups such as children, older and recreational-level athletes. While the possibilities for future studies seem endless, initial focus should be on investigating the sports with the highest participation levels and the groups considered to be at the greatest risk of overuse injury, such as elite adolescent athletes (DiFiori et al., 2014; Bahr, 2014).

It is also important that injury prevention research moves beyond the observational level. When specific injury problems are identified, risk factors should be investigated and prevention interventions tested (van Mechelen et al., 1992). In this regard, our group has already initiated a project to test an injury prevention program for overuse shoulder injuries in handball, based on the risk factors identified in this dissertation. Further work is also necessary to identify intrinsic risk factors for shoulder injuries among female players, and to investigate the relationship between throwing volume and injury. While the latter would involve substantial technical and statistical challenges, this information may enable the development of prevention strategies based on throwing load monitoring (Bahr, 2014). Such an approach, as currently used in youth baseball, is an attractive idea for the prevention of shoulder injuries in handball.

Secondary prevention, in the form of early identification and early intervention, is also a particularly relevant approach to reducing the impact of overuse injuries in certain groups of athletes. This dissertation demonstrates the viability of such an approach in the context of a national Olympic program. The methods developed to do this have significant practical and research applications in other, similar environments. They have already been used in studies of dancers in the Norwegian National Ballet Company (Fredriksen et al., 2014) and of young tennis players in the Royal Dutch Lawn Tennis Association's national high-performance program (Pluim et al., 2014). In addition, they have recently been used to monitor the Norwegian team in their preparations for the 2014 Winter Olympic and Paralympic Games in Sochi. We suggest that these methods could be adopted in a range of elite sporting environments, which would enable direct comparison of results, as well the pooling of data from relevant cohorts.

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Paper I

Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire

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ABSTRACT

Background Current methods for injury registration in sports injury epidemiology studies may substantially underestimate the true burden of overuse injuries due to a reliance on time-loss injury definitions.

Objective To develop and validate a new method for the registration of overuse injuries in sports.

Methods A new method, including a new overuse injury questionnaire, was developed and validated in a 13-week prospective study of injuries among 313 athletes from five different sports, cross-country skiing, floorball, handball, road cycling and volleyball. All athletes completed a questionnaire by email each week to register problems in the knee, lower back and shoulder. Standard injury registration methods were also used to record all time-loss injuries that occurred during the study period.

Results The new method recorded 419 overuse problems in the knee, lower back and shoulder during the 3-month-study period. Of these, 142 were classified as substantial overuse problems, defined as those leading to moderate or severe reductions in sports performance or participation, or time loss. Each week, an average of 39% of athletes reported having overuse problems and 13% reported having substantial problems. In contrast, standard methods of injury registration registered only 40 overuse injuries located in the same anatomical areas, the majority of which were of minimal or mild severity.

Conclusion Standard injury surveillance methods only capture a small percentage of the overuse problems affecting the athletes, largely because few problems led to time loss from training or competition. The new method captured a more complete and nuanced picture of the burden of overuse injuries in this cohort.

INTRODUCTION

Overuse injuries, defined as those without a specific, identifiable event responsible for their occurrence, may be a substantial problem in many sports. They are thought to be the predominant injury type in sports that involve long, monotonous training sessions, for example, cycling, swimming and long-distance running,[1–4] as well as in technical sports that involve the repetition of similar movement patterns such as throwing and jumping.[5–7] They may also be common in team sports such as football, handball and volleyball, particularly at an elite level and among young athletes when the total load on the athlete from training and competition increases rapidly.[8–10] However, when compared to acute, traumatic injuries such as anterior cruciate ligament ruptures and lateral ankle-ligament sprains, overuse injuries have received very little attention in the sports injury prevention literature.[11] Valid and reliable data on their magnitude and severity are scarce in almost all sports, and there are very few studies specifically aiming to prevent overuse injuries in sport.[12]

One possible explanation for the lack of knowledge on overuse injuries is that their typical presentation and characteristics make them difficult to record in epidemiological studies, when currently accepted methods of injury registration are used.[13] Symptoms such as pain or functional limitation most often appear gradually and may be transient in nature, and therefore it is likely that athletes will continue to train and compete despite the presence of overuse conditions, at least in the early phase. In the face of a worsening problem, athletes may try to adapt their training, for example, by refraining from the most aggravating activities or choosing an alternative form of exercise, and at some stage it is also likely that medical treatment will be sought for the injury. It is typically only after these attempts at injury management have failed that athletes will cease participation in training and competition. Furthermore, athletes may choose to defer time loss if possible, for example, by postponing rest or treatment until off-season periods which are not always covered in injury surveillance studies. Thus, it is likely that few overuse injuries lead to time loss from sport. In fact, cross-sectional surveys of athletes from a variety of different sports suggest that it is very common for athletes to continue to train and compete despite the presence of pain and reduced function from overuse injury.[1 8 13–15]

A vast majority of recently published injury surveillance, risk factor and prevention studies employ registration methods that are based on a consensus statement for the study of injuries in football, published in 2006 and later adapted for other sports.[16–19] Under these methods, injuries are registered prospectively by researchers or team medical personnel over the course of a study, using one of several possible injury definitions; all physical complaints regardless of their consequences (*any physical complaint* definition), injuries leading to the athlete seeking attention from a qualified medical practitioner (*medical attention* definition), or injuries leading to the athlete being unable to fully participate in normal training and competition (*time-loss* definition). Of these injury definitions, it

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would seem that the first two would be most appropriate for recording overuse conditions, as a 'time-loss' definition would only capture the very worst problems, or the so-called tip of the iceberg. However, apart from special cases such as during short-duration tournaments,[3 20–23] the 'any physical complaint' and 'medical attention' definitions are rarely used in injury studies.[13] Furthermore, irrespective of the injury definition chosen, time loss remains a fundamental component of 'standard' registration methods as it forms the basis for the measurement of injury severity.

We have recently made recommendations for new methodology for measuring the occurrence and severity of overuse injuries in sport.[13] We suggested that a questionnaire on overuse injuries should be administered to the entire cohort at regular occasions throughout the course of a study. The major benefits with this design would be that the degree of overuse symptoms could be determined for each athlete and monitored over time, and that injury severity measures could be based on changes in an athlete's function or sports performance limitation, rather than on the duration of time loss.

The primary objectives of this study were to develop such a method and to examine the extent to which it may provide greater information on overuse injuries in comparison to standard methods of injury registration. The first step in this process was to develop a new questionnaire suitable to measure the consequences of overuse injuries in sport. The questionnaire was then administered to a group of junior and senior elite Norwegian athletes from a variety of team and individual sports each week for a period of 3 months. During this time, injury registration was also conducted using standard methods as per current recommendations.[16 17 19]

METHODS

Development of an overuse injury questionnaire

Question generation and reduction

A new overuse injury questionnaire was developed during a series of group meetings at our institution, attended by sports physiotherapists, medical practitioners, sports injury epidemiologists, athletes and experts in questionnaire design. The intention was to create a questionnaire that could be applied to any overuse injury problem in any area of the body; however, for the purposes of this study, we chose to focus on three common areas of overuse injury among athletes, the knee, lower back and shoulder.

During the initial meetings, a draft list of questions was prepared that included items on injury symptoms, the consequences of overuse injuries on sports participation and performance, and the degree to which injury affected physical functions such as jumping, lifting and throwing.

Interviews were then conducted with athletes and team clinicians from a variety of sports to determine what they considered to be important consequences of overuse injuries, and to provide feedback on the appropriateness and understandability of the draft questions. There was general agreement that pain, limited participation in training and competition, and reduced sporting performance were all important consequences of overuse injury, with several athletes indicating that, of these, limited sports participation was the most important injury consequence. However, several instances arose where athletes felt that the area-specific questions on physical function were irrelevant. For example, cross-country skiers felt that questions relating to jumping and throwing ability were not good measures of injury consequences for their sport.

We therefore chose to eliminate all questions that were area-specific and related to particular functional activities, and to concentrate on recording pain levels and the consequences of injury on sports participation and sporting performance. After a second round of athlete interviews, four questions were agreed upon that serve as the basis for the assessment of any anatomical area. Figure 1 shows these questions applied to the knee. In studies with multiple anatomical area of interest, the 4 questions are repeated for each area, such that a study of two areas would consist of 8 questions and a study of three areas would consist of 12 questions. In formulating these questions, we chose to use the term 'problem' rather than 'injury', because we felt that

Part 1: Knee Problems

Please answer all questions regardless of whether or not you have problems with your knees. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

The term "knee problems" refers to pain, ache, stiffness, swelling, instability/giving way, locking or other complaints related to one or both knees.

Question 1

Have you had any difficulties participating in normal training and competition due to knee problems during the past week?

☐ Full participation without knee problems

☐ Full participation, but with knee problems

☐ Reduced participation due to knee problems

☐ Cannot participate due to knee problems

Question 2

To what extent have you reduced you training volume due to knee problems during the past week?

☐ No reduction

☐ To a minor extent

☐ To a moderate extent

☐ To a major extent

☐ Cannot participate at all

Question 3

To what extent have knee problems affected your performance during the past week?

☐ No effect

☐ To a minor extent

☐ To a moderate extent

☐ To a major extent

☐ Cannot participate at all

Question 4

To what extent have you experienced knee pain related to your sport during the past week?

☐ No pain

☐ Mild pain

☐ Moderate pain

☐ Severe pain

Figure 1 OSTRC Overuse Injury Questionnaire for knee problems.

Clarsen B, *et al*. *Br J Sports Med* 2013;**47**:495–502. doi:10.1136/bjsports-2012-091524

there was a much greater variation in athletes' interpretation of the term 'injury.' Before each anatomical area, the term problem was defined, for example 'pain, aching, stiffness, looseness or other complaints in one or both of your shoulders' and 'pain, aching, stiffness or other problems in your lower back'. We also decided not to ask athletes to attempt to differentiate between acute and overuse problems themselves, as some overuse injuries can have a rapid onset of symptoms and be experienced by an athlete as an acute injury.[13] Instead, we used the questionnaire to gather information on all types of problems and then manually separated acute injury problems from overuse injuries in the dataset post hoc based on an interview by a sports physiotherapist.

Severity score

The responses to each of the four questions shown above are allocated a numerical value from 0 to 25, and these are summed in order to calculate a severity score from 0 to 100 for each overuse problem. The response values were allocated such that 0 represents no problems and 25 represents the maximum level for each question. The values for intermediate responses were chosen in order to maintain as even a distribution from 0 to 25 as possible while still using whole numbers. Therefore, questions 1 and 4 are scored 0-8-17-25, and questions 2 and 3 are scored 0-6-13-19-25. The severity score can be used as an objective measure of the consequences of an overuse problem, and can also be plotted for each athlete and used to monitor the progress of overuse problems during the course of a study (see example of typical data in figure 2).

Analysis of psychometric properties of the questionnaire

A total of 1074 complete questionnaire responses from elite Norwegian athletes were analysed using SPSS statistics software (SPSS V.18, IBM Corporation, New York, USA) to determine the internal consistency of the questionnaire (Cronbach's α). A factor analysis was also performed using a principle component analysis extraction method. The component matrix was assessed in order to determine whether it would be necessary to weight the questions' contribution to the injury severity score. If the factor loading of each question varied by less than 10%, this was taken as a sign that weighting the responses would be of little value.[24]

Determination of the face validity of the new method

In order to establish the face validity of the new method's ability to identify and measure overuse problems at the knee, lower back and shoulder, it was applied in a 3-month study of 313 elite Norwegian junior and senior athletes from a variety of sports, including cross-country skiing, floorball, handball, road cycling and volleyball (table 1). During this period, the new questionnaire was administered to all subjects on a weekly basis. At the same time, a parallel registration of time-loss injuries was also conducted using standard methods of injury registration.

Inclusion

We approached team coaches and asked whether they were interested in participation in the study, and if they expressed interest, all athletes in the team were provided with information about the study and asked to consent to participation. The study was approved by the Norwegian Data Inspectorate and reviewed by the South-Eastern Norway Regional Committee for Research Ethics.

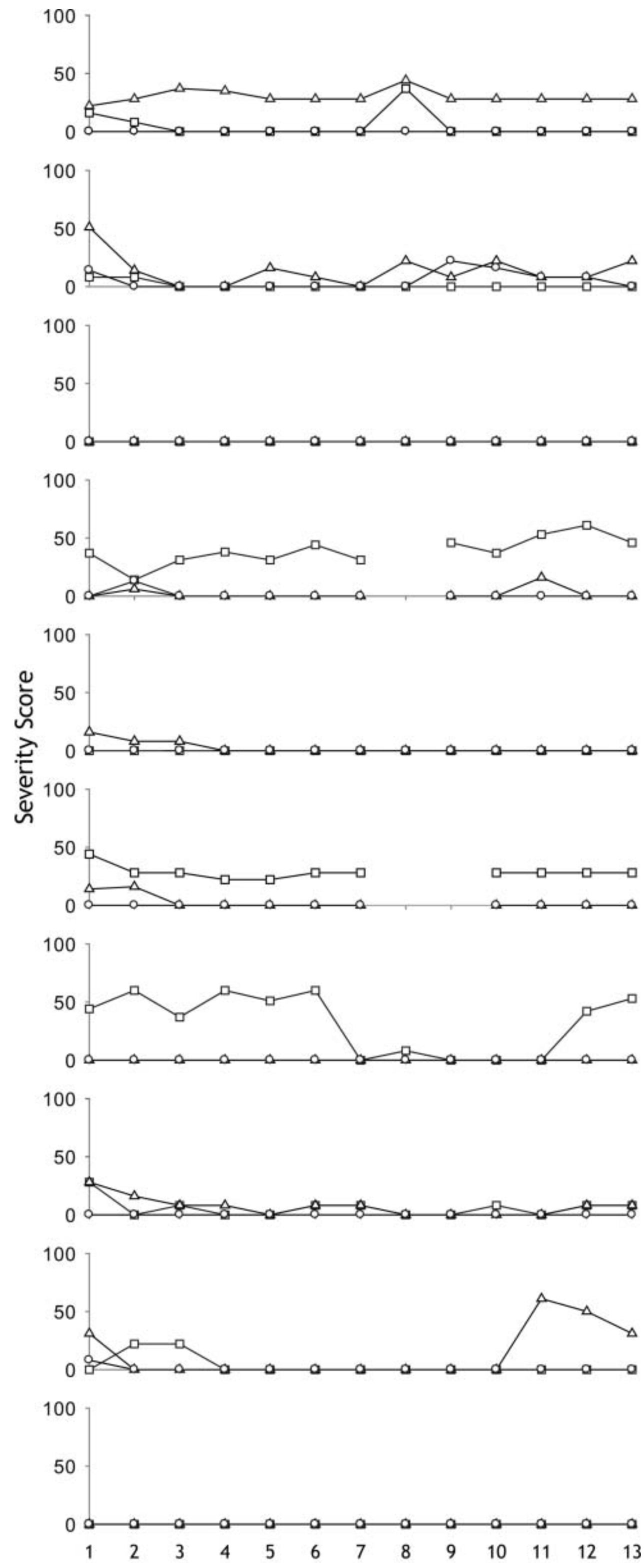

Figure 2 Examples of the severity score being used to track the consequences of overuse problems over the course of a 13-week study in 10 randomly selected athletes. Squares: knee severity score, triangles: lower back severity score, circles: shoulder severity score. Note that two athletes have missing data.

Injury registration: new method

Each athlete was asked to provide their email address when giving their written consent to participation in the study. Online

Table 1 Characteristics of the participants (n=313)

	Cycling (n=98)	Floorball (n=50)	Handball (n=55)	Volleyball (n=65)	XC skiing (n=45)
Female/male (n)	14/84	17/33	36/19	38/27	16/29
Age (year)*	21 (4)	22 (5)	20 (4)	18 (1)	18 (1)
Height (cm)*	181 (7)	176 (8)	177 (10)	179 (11)	177 (8)
Weight (kg)*	70 (7)	70 (9)	73 (13)	70 (10)	67 (8)
Years participating in the sport (n)*	6 (4)	9 (4)	12 (4)	6 (2)	10 (3)

*Values are shown as the mean with the standard deviation in parenthesis.
XC=cross-country.

survey software (Questback V. 9692, Questback AS, Oslo, Norway) was then used to send the overuse problem questionnaire to that address every week for 13 weeks. If no response had been received from an athlete after 3 days, they were automatically sent a reminder email, and if an athlete failed to respond for three consecutive weeks, they were contacted by telephone to encourage them to continue to participate in the project.

The questionnaire included the abovementioned four questions on the consequences of overuse problems at the knee, the lower back and the shoulder. These questions were preceded by a short introduction explaining that all questions should be completed, regardless of whether or not the athlete had experienced any problems in that area, and giving examples of the most common overuse symptoms for each area. The survey software prevented questionnaire submission if all items were not fully completed. The complete questionnaire is available as an online supplementary appendix in the online version of this article.

Injury registration: standard method

In the handball, floorball and volleyball teams, time-loss injuries were registered during scheduled training sessions by the team coach or physiotherapist, according to the methods described in the consensus statement for injury surveillance methods in football.[16] However, as road cyclists and cross-country skiers typically train individually rather than as a team, this was not possible in these groups. We therefore employed methods similar to those described by Nilstad *et al*,[25] whereby an extra question was added into their weekly questionnaires that asked whether they had had any form of physical complaint that prevented them from being fully able to train or compete in their sport. Any athletes that answered 'yes' to this question were contacted by a researcher on the telephone, and injuries that satisfied a time-loss injury definition were registered using standard methods. The extra question was added to the end of the questionnaire, after the specific questions on knee, lower back and shoulder problems had been answered. It was stated clearly that they should report any problem, regardless of whether or not they had already reported the same one in the previous questions.

Telephone interviews

At the conclusion of the study, all athletes were interviewed by a sports physiotherapist to confirm that all injury information we had received via both registration methods was correct. All injuries that were associated with a specific, identifiable event were classified as acute injuries. If an acute injury had been sustained in the knee, shoulder or lower back, data corresponding to these injuries that were obtained through the overuse injury questionnaires were separated in the database.

Data analysis

Each week the *prevalence* of overuse problems was calculated for each anatomical area by dividing the number of athletes that reported any type of problem in that area by the number of questionnaire respondents. A similar calculation was made for the number of athletes who reported problems leading to moderate or severe reductions in training volume, *or* moderate or severe reductions in sports performance *or* complete inability to participate in sport (ie, athletes who selected option 3, 4 or 5 in either Question 2 or Question 3). This is referred to as the *prevalence of substantial overuse problems*. The *average severity score* for each anatomical area was also calculated weekly by averaging the score of all athletes that reported a problem. At the conclusion of the study, the weekly average of these measures were calculated for each anatomical area: the average weekly prevalence of all problems, the average weekly prevalence of substantial problems, the average severity score and the average number of weeks that each problem was reported. A 95% confidence interval was calculated for each of these measures.

Modelling the effects of different sampling frequencies and removing the first questionnaire

In order to assess the effects of sampling less frequently, the abovementioned outcome measures were recalculated using only information from every second questionnaire and every fourth questionnaire. Outcome measures were also recalculated after removing the first questionnaire, and a related-samples Wilcoxon paired rank test was used to analyse differences between the first and second weeks in the prevalence of problems reported in each anatomical area in the five different sports.

RESULTS

Standard method

Weekly injury reports were completed by coaches of the handball, floorball and volleyball teams for every week of the project, and in the individual sports, all injuries reported at the end of the questionnaire were successfully registered by telephone interview. Using these methods, a total of 103 time-loss injuries, 42 acute and 61 overuse injuries, were recorded among 82 athletes during the course of the study (table 2). Of the 61 overuse injuries, 40 were located in the knee, lower back or shoulder; 18 were new injuries and 22 were recurrent injuries. These 40 injuries were distributed among 33 athletes, equating to 11% of the cohort. Most knee, lower back and shoulder injuries were of minimal severity (48%); 15% were mild, 25% moderate and 13% severe.

New method

The average weekly response rate to the overuse injury questionnaire was 93%, with 81% of athletes responding to all 13 questionnaires administered during the course of the study. A total of 419 overuse conditions were identified, affecting 236 athletes (75% of the cohort). Fifty-two per cent of all athletes registered conditions located at the knee, 43% at the shoulder and 40% at the lower back. Forty-four per cent of all problems were present at the beginning of the study. Of all overuse conditions, 17% only involved minor pain and did not have any consequences on sporting participation or performance, whereas 34% were classified as substantial problems. Thirty-six percent of the

Table 2 Location and severity of time-loss injuries identified by standard injury surveillance methods

	Minimal (1–3 days)	Mild (4–7 days)	Moderate (8–28 days)	Severe (>28 days)	Total
Acute injuries					
Head and face	3	0	2	0	5
Finger	0	1	1	0	2
Ribs	1	0	0	0	1
Lumbar spine	0	0	1	0	1
Pelvis/sacrum/ buttock	0	1	0	0	1
Thigh	2	0	1	0	3
Knee	2	1	3	0	6
Lower leg	1	0	0	0	1
Ankle	6	3	7	2	18
Foot/toe	1	1	2	0	4
Total	16	7	17	2	42
Overuse injuries					
Ankle	2	0	1	0	3
Foot/toe	0	0	1	0	1
Hip and groin	0	0	1	0	1
Knee	12	4	8	4	28
Lower leg	4	2	1	0	7
Lumbar spine	7	2	1	0	10
Pelvis/sacrum/ buttock	0	0	0	1	1
Shoulder	0	0	1	1	2
Wrist	0	0	1	0	1
Thigh	4	1	0	2	7
Total	29	9	15	8	61

cohort experienced a substantial problem at some stage during the course of the study. The average weekly prevalence of all problems and substantial problems, the average weekly severity score and the average duration of problems is shown in table 3. Figure 3 shows the number of cases recorded by the two different methods. Figure 4 illustrates data reported by the 10 athletes with the highest cumulative severity scores over the 3-month period. Of the 23 overuse conditions reported by these athletes, 7 were also recorded with the standard method.

Effects of different sampling frequencies on outcome measures

Sampling less frequently led to fewer cases being identified; however, the average prevalence and average severity measures were not affected (table 4). The greatest prevalence of overuse problems in all anatomical areas was reported in the first questionnaire ($p<0.01$), and reanalysis of the dataset after removing the first questionnaire led to a 14% reduction in the number of problems being identified without affecting the average prevalence or average severity score.

Psychometric questionnaire properties

The questionnaire had high internal consistency, with a Chronbach's α of 0.91. This was not improved any further by removing items (table 5). The factor weighting ranged from 0.86 to 0.91 for the four questions, suggesting that there is a little reason to weight items in the calculation of the severity score.

Table 3 Average weekly prevalence of all overuse problems and of substantial problems, average weekly severity score and average duration of cases

	Knee (161 cases)	Lower back (135 cases)	Shoulder (123 cases)
Average weekly prevalence (all problems)*	24 (21–27)	16 (13–19)	12 (10–15)
Average weekly prevalence (substantial problems)*	8 (7–8)	3 (2–4)	2 (2–3)
Average weekly severity score	31 (30–32)	24 (22–25)	24 (22–25)
Average duration of cases (weeks)†	6 (5–6)	4 (4–5)	4 (3–5)

*Values are shown as percentages with the 95% CI in parentheses.
†95% CI in parentheses.
Substantial problem: overuse problem causing moderate/severe reductions in training volume or sports performance or complete inability to participate in training or competition.

DISCUSSION

The ability to validly and reliably record overuse conditions presents a particular problem in sports injury epidemiology, largely due to the fact that athletes often continue to train and compete despite the existence of overuse problems. This study clearly highlights the inadequacy of currently accepted injury registration methods to record the true magnitude of overuse problems, given that the new method identified more than 10 times as many cases than the standard method and demonstrated that 75%, rather than 11%, of athletes were affected during the 3-month study period. However, objective comparison of the two methods is difficult as we are proposing a completely different paradigm for the recording and reporting of overuse problems. An appraisal of the potential benefits and limitations of the new method must therefore be largely qualitative in nature.

The first factor that prevents direct comparison of the results of each method is that we have not only compared two different ways of collecting injury data but also two different injury definitions. The standard method used a time-loss definition, only recording injuries that lead to a cessation of training or competition for at least 1 day, whereas the new method recorded all physical complaints even if the only symptom was mild pain. A far greater number of problems would therefore be expected to have been captured using the all physical complaints definition, regardless of the registration methods used. Although it would

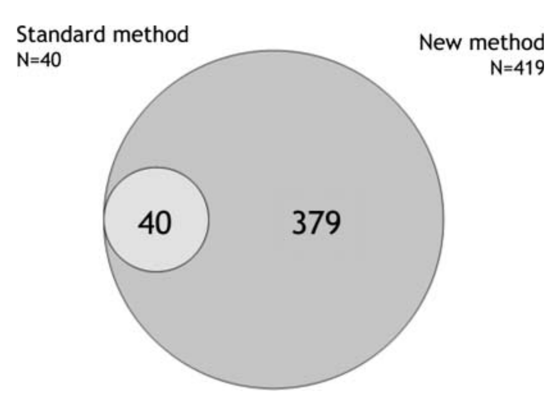

Figure 3 Venn diagram of the number of overuse problems identified by the standard injury registration method and the new method. All injuries registered using the standard method was classified as substantial overuse problems by the new method.

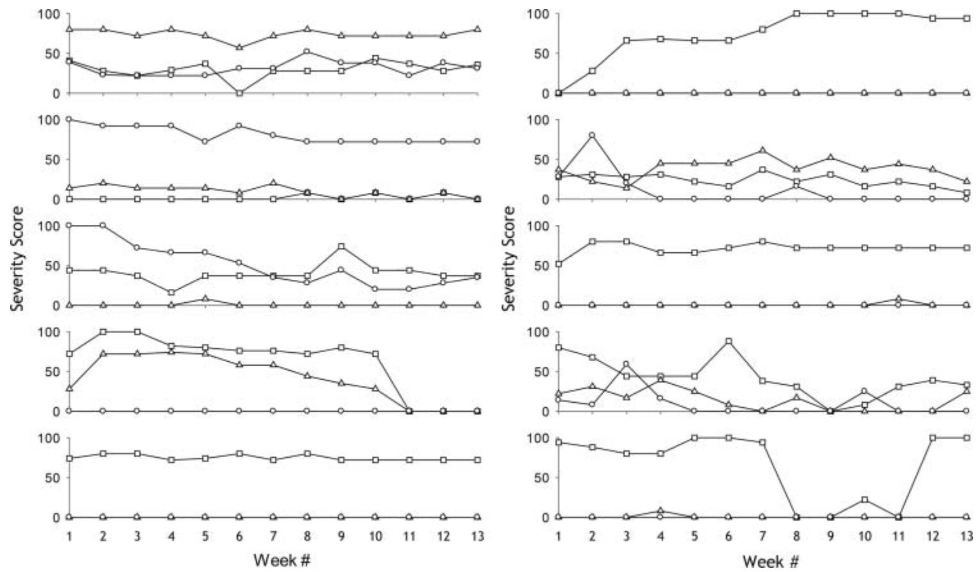

Figure 4 Athletes with the 10 highest cumulative severity scores during the 13-week study. Squares: knee severity score, triangles: lower back severity score, circles: shoulder severity score.

have been possible to have used a similar definition for the standard method, we chose to use a time-loss definition because it is currently the most commonly used definition in the recent sports epidemiology literature.[13] Broader definitions, such as all physical complaints or medical attention, may be seldom used because they greatly increase the burden on injury recorders and because there are concerns over their reliability of the information they collect. For example, the number of injuries recorded will vary depending on the extent of contact between injury recorders and athletes, and different injury recorders are likely to have differing interpretations of what constitutes a recordable event.[26] In contrast, the new method may be less susceptible to these sources of bias as data are reported directly by athletes rather than third-party injury recorders. While the information collected remains subjective, it reflects the consequences of overuse problems that are relevant for each athlete and this is unlikely to vary systematically between different cohorts. The ability to compare broad-definition injury data between studies is therefore greatly enhanced using the new method.

A second factor that prevents direct comparison of the two methods is that each one expresses the rate and severity of injuries in different ways. Traditionally, injury rates are expressed as an incidence, most often as the number of new injuries per 1000 h of sports participation.[27] However, incidence fails to account for injuries that are present at the start of a study, and this may preclude the registration of a large proportion of overuse problems. For example, in the present study, 44% of cases identified using the new method would have been excluded from incidence calculations for this reason. We therefore chose to express the rate of overuse problems as an average prevalence with a 95% CI. This effectively reflects the proportion of athletes that could be expected to be affected by overuse problems at any given point during the study. The average prevalence of substantial problems was also reported, as this measure filters out the most minor problems and thereby provides important information on the true burden of overuse injury among a group of athletes.

Table 4 Variations in outcome measures with different sampling frequencies

	Sample weekly	Sample weekly exclude week 1	Sample every 2 weeks*	Sample every 4 weeks†
Number of completed questionnaires	3848	3538	1774	896
Number of problems	419	361	318	280
Number of substantial problems	142	124	94	72
Average prevalence (all problems)	39 (34–44)	37 (34–41)	39 (34–44)	40 (31–50)
Average prevalence (substantial)	13 (12–15)	12 (11–14)	13 (10–15)	13 (9–17)
Average severity score	28 (27–29)	28 (27–29)	28 (26–29)	27 (26–27)
Average duration of problems (weeks)	5 (4–5)	5 (4–5)	3 (1–4)	2 (1–2)

*Weeks 2, 4, 6, 8, 10 and 12
† Weeks 2, 6 and 10.

Table 5 Inter–item and item–total correlations and effects of removing items on internal consistency

	Inter–item correlation matrix				
	Question 1	Question 2	Question 3	Item–total correlation	Cronbach's α if item deleted
Question 1	–			0.80	0.88
Question 2	0.70	–		0.74	0.90
Question 3	0.75	0.72	–	0.85	0.85
Question 4	0.73	0.64	0.80	0.82	0.87

Clarsen B, *et al*. *Br J Sports Med* 2013;**47**:495–502. doi:10.1136/bjsports-2012-091524

Injury severity is also expressed in different ways by the two methods. Traditionally, it is expressed as the number of days taken from the time of injury until the athlete resumes full training and competition, and if the injury does not lead to time loss, it is recorded as being of '0 days' severity. In the current study, this situation applied to a majority of overuse problems, despite the fact that many of these so-called 'slight' problems led to reduced performance, pain and modified participation that lasted for many weeks. Clearly, basing severity on time loss alone underestimates the true impact of overuse problems. Furthermore, even when an overuse problem does cause time loss, it is often interspersed between repeated attempts to return to training and competition.[13] Although suggestions have been made on how to deal with such problems,[28] most studies using standard methods adopt return-to-play criteria for defining injury resolution, meaning that fluctuating problems are treated as separate events, each time the athlete returns to full training and competition. This is obviously an invalid representation of the true nature of such injuries.

The new method therefore measures the severity of overuse problems using the severity score, which reflects the athlete's self-assessment of their pain and the impact that the problem has had on their participation, training volume and sports performance. Due to the subjectivity of this method, the validity of directly comparing individual athlete's questionnaire responses is questionable; however, the severity score is useful in monitoring the progression of overuse problems over time, such as in the examples displayed in figures 2 and 3. This approach may be of particular benefit if the new method is used as a practical injury surveillance tool. Furthermore, as there is little reason to suspect a systematic bias in severity scores between different groups of athletes, the average severity score can be used as the basis for comparison between groups. Future studies may also calculate the area under each athlete's injury curve such as those shown in figures 2 and 4, and use that number as a reflection of the total burden of each overuse problem. In this way, a long duration problem of mild or moderate severity may be scored higher than a more severe one that is only of a brief duration. This technique may be particularly relevant when applying the new method in risk factor and prevention studies; however, missing data will be a complicating factor when making these calculations.

A final advantage of the new method is that it is likely to be a cheaper alternative than traditional methods of data collection as once the survey software has been set up, all questionnaires and reminders are automatically delivered each week for the duration of the study. This is likely to be far less costly than paying research staff to manually record injuries.

The new method does, however, have several limitations. First, as information is based on athlete self-reports and the definition of a recordable problem is very broad, it is possible that some of the cases recorded may in fact be 'normal' pain related to athletic participation rather than an overuse injury, for example, delayed-onset muscle soreness. This may be particularly relevant for the 17% of cases that only involved minor pain and had no consequences on sports performance or participation. Ideally, the solution to this problem is that each problem reported by an athlete is quickly followed up with a confirmatory medical examination; however, this obviously increases the logistical difficulty and cost of conducting a study.

A second limitation of the method is that the validity of the recorded information is dependent on a high response rate throughout the course of the study. As the burden of injury registration is placed upon athletes, much attention and effort needs to be paid to motivating them to respond to each questionnaire. In the current study, the average response rate of 93% was very high; however, it is unknown whether such a good rate could have been maintained over a longer period of time. Future studies that involve a longer duration of data collection may need to be performed with less frequent questionnaire administration, for example, every second week or every month. This may also be the case for studies of recreational or non-elite athletes who may be less motivated to report injury data so frequently. In order to assess the effect of this, we performed data simulations with information from every second and every fourth questionnaire. The results indicate that when sampling less frequently, the average prevalence and severity score measures remain unchanged, while the number of problems identified is reduced. Based on these findings, sampling less frequently may be acceptable; however, if this is done, it is important to recognise that some shorter duration problems will be missed. We recommend that regardless of the sampling frequency, the retrospective period of registration of problems should not extend beyond 7 days, in order to minimise the risk of recall bias.

In our data simulation, we also analysed the effect of removing the results of the first questionnaire from the dataset. This led to a slight reduction in the number of reported cases, but did not affect the average prevalence measures or the severity score. We performed this analysis because the first questionnaire identified the highest prevalence of overuse problems in every anatomical area in every group of athletes, and this could not be explained by seasonal variation as the data were not collected at exactly the same time, and each group of athletes were in different periods of their season during the collection period. We therefore suspect that the first questionnaire returns an artificially high rate of overuse problems, and suggest that with future use of the new method these data should be excluded from the final dataset.

The new method is also dependent on the athletes providing honest information, which may be a concern if they feel that reporting an overuse problem may have adverse effects for them, such as on their chances of team selection. In order to minimise this risk, we were careful to explicitly guarantee confidentiality in the information letter prior to the study and in the introduction to the questionnaire they received each week. However, as with all forms of injury surveillance, it is hard to verify the extent to which athletes report the truth and this remains a threat to the validity of the data.

Another limitation to the new method is that the amount of details that can be collected directly from athletes is limited. The questionnaire only collects information on the anatomical location of each problem, rather than the injury type or specific diagnosis. This is because we do not expect that athletes will be able to reliably report this information, which should ideally be based on a clinical examination. Similarly, in the current study, we used telephone interviews to differentiate between acute and overuse injuries because we were concerned that so-called sudden-onset overuse injuries may have been misclassified if athletes had been asked to differentiate between the two types themselves. However, this approach is not without problems as it limits the potential sample size of a study and retrospective telephone interviews are subject to interviewer and recall bias. Alternative means of differentiating between acute injuries and overuse problems may be necessary in future studies.

A final limitation of the new method is that in its current form it only collects data on predefined injury areas. The method therefore needs to be modified in order to be used in studies where the research objective is a general registration of all types of overuse problems. However, when the objective is to study specific overuse problems, the current approach may be preferable as previous studies have shown that general questioning on overuse injuries leads to fewer problems being identified than when specific questions on predefined areas are used.[1]

CONCLUSION

We have developed a new method for the registration of overuse problems in sports injury epidemiology. As demonstrated by this study, the new approach offers several advantages over standard methods, particularly as it allows for the use of a broad injury definition and a means of quantifying injury severity that is not dependent on time loss. The new method may therefore be a better alternative for the specific study of overuse problems in sport.

What are the new findings?

- Standard methods of injury registration using a time-loss injury definition may be insufficient for the study of overuse injuries.
- When studying overuse injuries, all physical complaints need to be recorded and severity measures need to be based on pain and the consequences of injury on athletes' participation and sporting performance.
- The rate of overuse problems should be expressed using prevalence and severity measures, rather than incidence.

How might it impact on clinical practice in the near future?

- This paper may lead to a change in the methods that are used to register the magnitude and severity of overuse problems in epidemiological studies of sports injuries.

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Correction notice This article has been corrected since it was published Online First. The section ': the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire' has been added to the title. The text reference to figure 1 has also been corrected.

Contributors All authors were involved in planning the project, the development of the questionnaire and in writing the manuscript. BC was also responsible for coordination of the data collection and for data analysis. BC is responsible for the overall content as guarantor.

Competing interests None.

Ethics approval South-Eastern Norway Regional Committee for Research Ethics.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement All unpublished data are available upon request. However, we are planning a second article based on the same data set describing the prevalence and severity of overuse injuries in each of the five sports. This paper will shed additional light on the validity of the new method.

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Paper II

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The prevalence and impact of overuse injuries in five Norwegian sports: Application of a new surveillance method

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Little is known about the true extent and severity of overuse injuries in sport, largely because of methodological challenges involved in recording them. This study assessed the prevalence of overuse injuries among Norwegian athletes from five sports using a newly developed method designed specifically for this purpose. The Oslo Sports Trauma Research Center Overuse Injury Questionnaire was distributed weekly by e-mail to 45 cross-country skiers, 98 cyclists, 50 floorball players, 55 handball players, and 65 volleyball players for 13 weeks. The prevalence of overuse problems at the shoulder, lower back, knee, and anterior thigh was monitored throughout the study and summary measures of an injury severity score derived from athletes' questionnaire responses were used to gauge the relative impact of overuse problems in each area. The area where overuse injuries had the greatest impact was the knee in volleyball where, on average, 36% of players had some form of complaint (95% CI 32–39%). Other prevalent areas included the shoulder in handball (22%, 95% CI 16–27%) the knee in cycling (23%, 95% CI 17–28%), and the knee and lower back in floorball (27%, 95% CI 24–31% and 29%, 95% CI 25–33%, respectively).

In recent years, increasing attention has been drawn to the challenge of accurately measuring the extent and severity of overuse sports injuries in epidemiological research. By definition, overuse injuries are the result of a cumulative process of tissue damage rather than instantaneous energy transfer (Cook & Finch, 2011; Bahr et al., 2012; Finch & Cook, 2013). In most cases, therefore, the onset of overuse-related symptoms and disability is gradual and the point at which they can be called an "injury" is blurred. It is well documented that athletes often continue to train and compete despite the existence of overuse injuries and that their threshold for ceasing sports participation may be high, particularly at an elite level (Bahr, 2009). Traditional injury surveillance systems, which rely on a clearly identifiable onset and which use the duration of time-loss from sport as the sole means of measuring severity, may therefore be inappropriate for studying overuse injuries (Bahr, 2009).

In order to address these challenges, we have recently developed a new approach to recording the extent of overuse sports injuries (Clarsen et al., 2013). The method involves the administration of an overuse injury questionnaire to an entire group of athletes at regular intervals throughout the duration of a study, with primary outcome measures based on the prevalence of overuse problems (the percentage of athletes with complaints at a given time point) rather than injury incidence (number of new cases during the observation period).

As a part of the development and validation of this method, we used it in a prospective study of Norwegian athletes from five different sports: cross-country skiing, road cycling, floorball, handball, and volleyball (Clarsen et al., 2013). However, the validation study used pooled data from all sports, as it was beyond its scope to describe and discuss the results of each sport individually. As little high-quality information exists on the extent of overuse injuries in these five sports, the main aim of this paper is to describe the extent of overuse problems in each sport. This paper is also intended to test the application of the new method for recording overuse injuries in sport and demonstrate how comparisons can be made between groups using repeated measures of prevalence, how summary measures of injury severity can be used to contrast the impact of overuse problems between and within groups, and how missing questionnaire data can be handled using multiple imputation (MI) techniques.

Methods

This was a prospective cohort study using a panel design. Online survey software (Questback vs 9692, Questback AS, Oslo, Norway) was used to distribute the Oslo Sports Trauma Research Center

Overuse Injury Questionnaire (Clarsen et al., 2013) to all athletes in the study each week for 13 weeks during the period October 2010–March 2011. E-mails linking athletes to the questionnaire were sent every Sunday, and a reminder e-mail sent to nonresponders 3 days later. The questionnaire consisted of four questions on each anatomical area of interest (Clarsen et al., 2013); athletes in all groups received questions related to the knee, lower back, and shoulder, while cyclists and cross-country skiers also received questions on the anterior thigh. The complete questionnaire is available as online Supporting Information to this article.

Within a month of the final questionnaire, all athletes were contacted by a physiotherapist for a telephone interview to review their questionnaire responses and determine the type and nature of each problem reported. Based on these interviews, all cases were classified as either acute or overuse injuries and separate datasets were created for each injury type. Acute injuries were defined as those associated with a specific, clearly identifiable injury event. All other cases were regarded as overuse injuries, regardless of whether their onset was gradual or rapid. Recurrent overuse conditions at the same location and of the same nature were treated as a single case despite periods of symptom remission (Finch & Cook, 2013).

Participants

All study participants competed on the highest level of competition in Norway at either a senior or under-19 (junior) level. The cross-country skiers ($n = 45$) were recruited from a junior team representing the Oslo region. Road cyclists ($n = 98$) were recruited from five semi-professional teams, one professional women's team, and five junior teams. Floorball players ($n = 50$) were recruited from men's and women's elite club teams and the junior men's team from a large club in Oslo. This was similar for handball players ($n = 55$), who were recruited from the men's and women's elite teams and junior women's teams from an Oslo club. Volleyball players ($n = 65$) were recruited from a special boarding school that combines a 3-year senior high school program with daily volleyball training for all students. The teams included in the study were a convenience sample and there was a wide variation in the distribution of athletes' age, sex, height, body mass, and number of years of participation in the sport between the five groups, as shown in Fig. 1. The study was approved by the Norwegian Data Inspectorate and reviewed by the South-Eastern Norway Regional Committee for Research Ethics. All athletes provided written informed consent to participation.

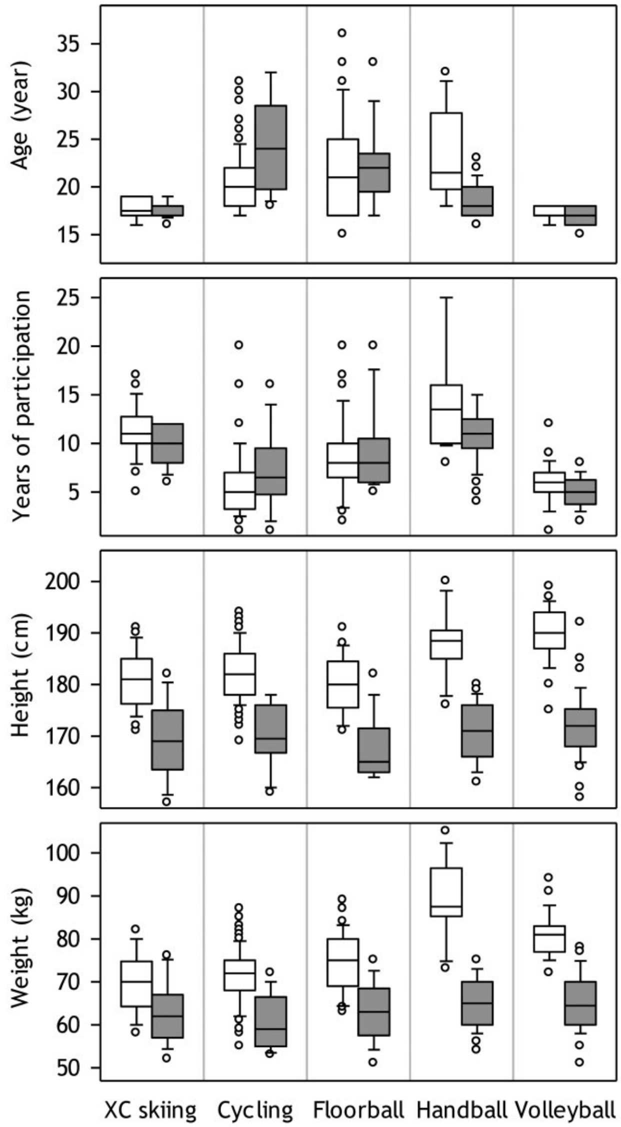

Fig. 1. Boxplot comparisons of the demographic characteristics of males (white boxes) and females (shaded boxes) from each of the five sports; cross-country (XC) skiing (29 males/16 females), cycling (84/14), floorball (33/17), handball (19/36), and volleyball (27/38).

Prevalence measures

The prevalence of overuse problems was calculated for each anatomical area each week of the study by dividing the number of athletes that reported any problem (i.e., anything but the minimum value in any of the four questions) by the number of questionnaire respondents. Weekly prevalence data were plotted over time to identify trends over the course of the study, and the average weekly prevalence of overuse problems was calculated for each anatomical area and athlete group. As all physical complaints were included in this measure, regardless of their consequence on sports participation or performance, the injury definition used is consistent with the recommendations of methodological consensus statements from a variety of sports (Fuller et al., 2006, 2007; Pluim et al., 2009).

A second prevalence measure was also calculated for each anatomical area and sporting group; the average prevalence of substantial overuse problems. This was calculated and expressed in the same way as described above. However, the numerator in the prevalence calculations only included overuse problems leading to (self-reported) moderate or severe reductions in training volume or sporting performance, or a total inability to participate (i.e., responses 3, 4, or 5 in either question 2 or 3). This was done in order to filter out the most minor overuse problems from prevalence measures.

Relative impact of overuse problems

Every time an athlete responded to a questionnaire, a severity score was calculated for each anatomical area, based on their responses to the four key questions (Clarsen et al., 2013). At the conclusion of the study, a cumulative severity score was calculated for each area for each sporting group by summing athletes' severity scores over the 13 weeks, adjusted for differing group sizes and response rates. These scores were compared as an assessment of the relative impact of overuse problems in each anatomical area within and between sports.

Statistical procedures

Missing data

Preliminary analyses showed that, on average, 6.6% of data were missing in each of the repeated outcome measures and that 19% of subjects had incomplete datasets. The patterns of missing data were then analyzed in two ways. Firstly, univariate and multivariable logistic regression analyses were performed to assess whether baseline variables (sport, gender, age and years of sports participation) were associated with missing follow-up data. Secondly, logistic regression analyses were performed to evaluate if outcome data at specific follow-up points were related to missing data at the next follow-up point. These analyses revealed that demographic characteristics were not statistically predictive of incomplete data. However, nonresponse to one questionnaire was predictive of nonresponse the following week. This indicated that information from previous outcome measures could be used to predict outcome at later time points, which is a strong reason for assuming it to be of the type "missing at random" (van Buuren, 2012). We therefore used the MI method to handle the missing data, which led to the pooled results of five multiple imputed datasets. MI was based on the Multivariate Imputation by Chained Equation algorithm in combination with a predictive mean matching approach, as currently implemented in SPSS statistical software (SPSS V.21, IBM Corporation, New York, USA; van Buuren, 2012). Sensitivity analyses were performed comparing the MI results with complete-case analyses (i.e., deleting each case with missing data before the analysis). As these analyses showed no differences in results, we chose to report all statistical analyses using the imputed data.

Comparison of sporting groups

In order to assess differences in the prevalence of all overuse problems and substantial overuse problems between sporting groups over time, generalized estimating equations (GEE) were performed using SPSS software. GEE accounts for the correlation of repeated outcome measures within subjects over time. We chose GEE in preference to a generalized linear mixed model because we were interested in group-averaged compared with person-specific relationships. Subject age, gender, years of sports participation, height, and weight were included in the GEE models, as univariate analyses of each of these factors revealed a possible association with the various injury outcomes over time ($P < 0.2$). An exchangeable covariance matrix was used and the significance level (α) was 0.05 for all analyses.

Results

Response rate

The response rate to the 13 weekly questionnaires was 96% in cross-country skiing, 92% in cycling, 90% in floorball, 98% in handball, and 91% in volleyball. Eighty-one percent of athletes answered all 13 questionnaires and 91% answered 11 or more.

Prevalence of overuse problems

The prevalence of all overuse problems and of substantial overuse problems in each anatomical location over the 13 weeks is illustrated in Fig. 2. As illustrated in the figure, the prevalence of all problems tended to be highest at the beginning of the study in all groups, whereas the prevalence of substantial problems remained relatively stable throughout the 13 weeks.

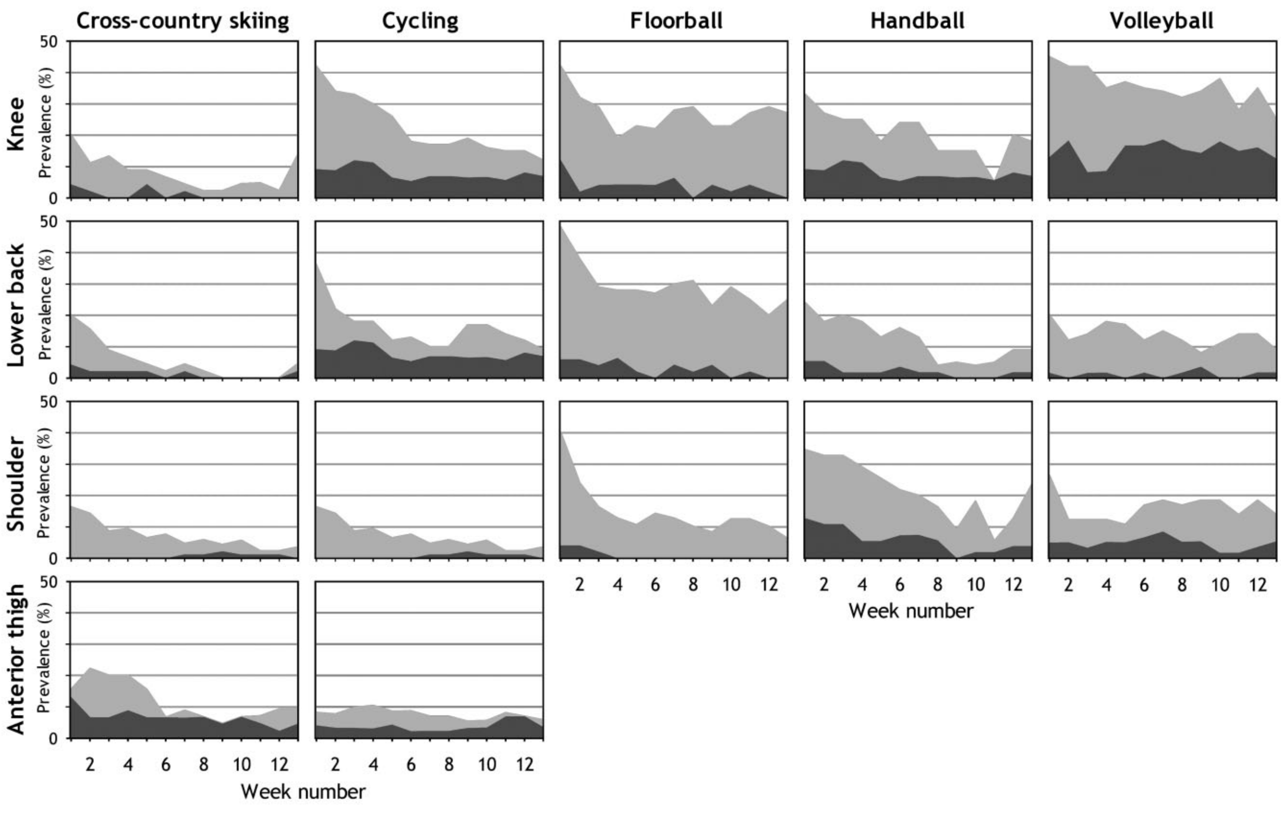

Fig. 2. Prevalence of all overuse problems (light gray area) and substantial overuse problems (dark gray area) located in the knee, lower back, shoulder, and anterior thigh in each of the five sports over 13 weeks.

Table 1. Average prevalence of all overuse problems and of substantial problems, % (95% CI)

	XC skiing	Cycling	Floorball	Handball	Volleyball
All overuse problems					
Knee	8 (5–11)	23 (17–28)	27 (24–31)	20 (16–25)	36 (32–39)
Lower back	5 (2–9)	16 (12–20)	29 (25–33)	12 (8–16)	14 (11–16)
Shoulder	1 (0–3)	7 (4–10)	15 (9–20)	22 (16–27)	16 (14–19)
Anterior thigh	12 (8–15)	8 (7–9)			
Substantial overuse problems					
Knee	1 (0–2)	8 (7–9)	4 (2–6)	8 (6–10)	15 (13–17)
Lower back	1 (1–2)	6 (4–7)	3 (1–4)	2 (1–3)	1 (1–2)
Shoulder	1 (0–1)	1 (0–1)	1 (0–2)	6 (4–8)	5 (4–6)
Thigh	7 (5–8)	4 (3–5)			

Substantial overuse problem: causing moderate/severe reductions in training volume or sports performance, or complete inability to participate in training or competition.
XC, cross-country.

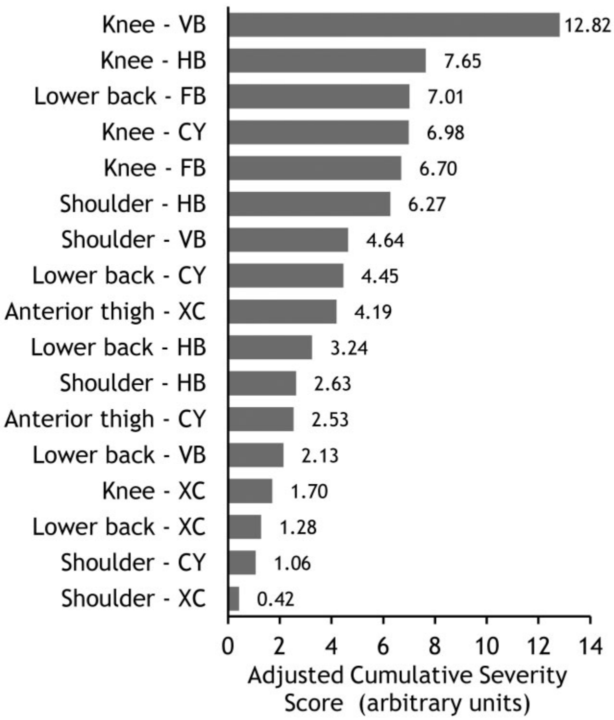

Fig. 3. Relative impact of overuse problems located in the knee, lower back, shoulder, and anterior thigh between the different sporting groups, shown as the adjusted cumulative severity score for each group. CX, cross-country skiing; CY, road cycling; FB, floorball; HB, handball; VB, volleyball.

Table 1 shows the average prevalence of all overuse problems and of substantial overuse problems for each anatomical area in all sports.

Relative impact of overuse problems

Figure 3 shows the relative impact of overuse problems in each anatomical area for each sport, based on the adjusted cumulative severity score over the 13-week study. As shown in the figure, knee problems among volleyball players had the greatest relative impact.

Inter-sport comparisons

The odds ratios of experiencing overuse problems between each sport are shown in Table 2. All calculations are adjusted for the effect of athletes' demographic characteristics. Table 3 shows the relationships between demographic characteristics and the various injury outcomes, based on multivariable GEE analyses. As shown in the table, female athletes had a reduced risk of substantial knee and lower back problems, lighter athletes had an increased risk of substantial knee problems, and heavier athletes had an increased risk of thigh problems and substantial thigh problems.

Discussion

In this paper, we have measured the prevalence and impact of overuse problems across a variety of sports using a new method designed specifically for this purpose. Comparisons were made between groups primarily in order to illustrate how the new method can be applied for this purpose. Several particular problem areas were identified, such as knee complaints among the volleyball players, which was the most prevalent overuse problem that we measured and clearly the one posing the greatest impact on the athletes. While this finding is supported by those of previous studies that used different methods of data collection, in other cases, our results were contrary to previous reports.

The rate of overuse problems was generally low among cross-country skiers, with the lowest prevalence of knee, shoulder, and lower back problems of all the sports. The latter finding contrasts with several previous studies, which suggest that lower back pain may be a particular problem among high-level cross-country skiers (Orava et al., 1985; Eriksson et al., 1996; Bahr et al., 2004; Bergstrom et al., 2004; Alricsson & Werner, 2005, 2006). However, of these investigations, four did not consider the extent to which lower back pain affected participation and skiing performance, and one of the two that did so concluded that while back pain was relatively common among young elite skiers, its effect

Table 2. Multivariable adjusted odds ratios of overuse problems in the knee, lower back, shoulder, and anterior thigh between the five different sports

	XC skiing	Cycling	Floorball	Handball
Knee problems (all overuse)				
Cycling (ref)	0.43 (0.16–1.13)			
Floorball (ref)	0.42 (0.16–1.13)	0.98 (0.50–1.90)		
Handball (ref)	0.36 (0.14–0.93)*	0.83 (0.33–2.08)	0.85 (0.33–2.17)	
Volleyball (ref)	0.18 (0.07–0.49)*	0.43 (0.21–0.86)*	0.44 (0.19–1.00)*	0.51 (0.22–1.20)
Substantial overuse knee problems				
Cycling (ref)	0.30 (0.09–1.04)			
Floorball (ref)	0.41 (0.12–1.40)	1.36 (0.56–3.34)		
Handball (ref)	0.09 (0.03–0.35)*	0.32 (0.08–1.35)	0.23 (0.06–0.83)	
Volleyball (ref)	0.08 (0.02–0.28)*	0.27 (0.10–0.70)*	0.20 (0.07–0.54)*	0.85 (0.29–2.52)
Lower back problems (all overuse)				
Cycling (ref)	0.57 (0.20–1.62)			
Floorball (ref)	0.35 (0.13–0.92)*	0.60 (0.32–1.15)		
Handball (ref)	0.66 (0.25–1.71)	1.14 (0.45–2.88)	1.90 (0.77–4.68)	
Volleyball (ref)	0.68 (0.25–1.90)	1.19 (0.56–2.52)	1.98 (0.83–4.63)	1.04 (0.41–2.63)
Substantial overuse lower back problems				
Cycling (ref)	0.29 (0.07–1.25)			
Floorball	0.64 (0.14–2.84)	2.17 (0.90–5.23)		
Handball (ref)	0.60 (0.15–2.36)	2.05 (0.68–2.35)	0.94 (0.26–3.39)	
Volleyball (ref)	0.33 (0.08–1.43)	1.13 (0.40–3.17)	0.52 (0.14–1.92)	0.55 (0.18–1.71)
Shoulder problems (all overuse)				
Cycling (ref)	0.20 (0.04–0.93)*			
Floorball (ref)	0.10 (0.02–0.43)*	0.49 (0.25–0.97)*		
Handball (ref)	0.08 (0.02–0.30)*	0.39 (0.16–0.91)*	0.78 (0.34–1.77)	
Volleyball (ref)	0.11 (0.02–0.54)*	0.57 (0.25–1.33)	1.15 (0.48–2.78)	1.48 (0.63–3.48)
Substantial overuse shoulder problems				
Cycling (ref)	1.02 (0.09–11.63)			
Floorball (ref)	0.35 (0.06–2.16)	0.35 (0.06–2.06)		
Handball (ref)	0.08 (0.02–0.36)*	0.08 (0.01–0.51)*	0.24 (0.07–0.76)*	
Volleyball (ref)	0.24 (0.02–0.83)*	0.13 (0.02–0.99)*	0.38 (0.07–2.12)	1.61 (0.44–5.95)
Anterior thigh problems (all overuse)				
Cycling (ref)	1.48 (0.46–4.79)			
Substantial overuse anterior thigh problems				
Cycling (ref)	1.85 (0.43–7.99)			

*$P < 0.05$.
All data are odds ratios with 95% confidence intervals in parentheses. Based on GEE analyses adjusted for age, sex, years of sports participation, height, and weight.
Ref, reference group; XC, cross-country.

Table 3. Multivariable analyses of the effect of demographic variables on the odds ratios for overuse and substantial overuse problems

	Female sex	Age (year)	Participation (year)	Height (cm)	Body mass (kg)
All overuse problems					
Knee	0.80 (0.38–1.68)	1.04 (0.97–1.12)	0.96 (0.88–1.04)	1.00 (0.95–1.04)	1.01 (0.97–1.02)
Lower back	0.99 (0.45–2.14)	1.06 (0.98–1.15)	0.96 (0.88–1.04)	0.97 (0.93–1.02)	1.02 (0.99–1.04)
Shoulder	1.79 (0.73–4.35)	1.05 (0.97–1.13)	1.01 (0.93–1.10)	1.01 (0.96–1.07)	1.01 (0.99–1.04)
Anterior thigh	0.74 (0.20–2.75)	1.04 (0.93–1.17)	1.00 (0.88–1.14)	0.98 (0.93–1.04)	1.02 (1.01–1.04)*
Substantial overuse problems					
Knee	0.28 (0.11–0.70)*	1.03 (0.95–1.13)	0.95 (0.85–1.06)	1.02 (0.96–1.09)	0.95 (0.90–1.00)*
Lower back	0.27 (0.07–0.96)*	1.02 (0.91–1.13)	1.00 (0.89–1.11)	0.96 (0.90–1.02)	1.00 (0.94–1.06)
Shoulder	2.95 (0.55–15.75)	1.01 (0.82–1.24)	1.00 (0.83–1.21)	1.04 (0.94–1.15)	1.01 (0.95–1.07)
Anterior thigh	0.88 (0.13–5.96)	1.09 (0.94–1.26)	1.03 (0.88–1.21)	0.98 (0.91–1.06)	1.02 (1.00–1.03)*

*$P < 0.05$.
All data are odds ratios per unit change in independent variables, with 95% confidence interval in parentheses. Based on GEE analyses adjusted for sporting group.

on their skiing ability was negligible (Eriksson et al., 1996). Based on our results, we concur with this conclusion.

In comparison to the knee, lower back, and shoulder, the prevalence of anterior thigh problems was relatively high among the cross-country skiers. While there is little documentation of this in the literature, it is our clinical experience that disabling quadriceps muscle pain and fatigue is a common overuse condition among young elite skiers. This opinion was shared by the coaches of the athletes involved in this study, who specifically asked that questions on the anterior thigh be included for cross-country skiers. Our results suggest that this is an area warranting further research.

All previous studies of overuse injuries among elite road cyclists have found the knee is a commonly affected area of injury (Callaghan & Jarvis, 1996; Barrios et al., 1997; Clarsen et al., 2010; de Bernado et al., 2012). Our findings certainly support this, given the large number of cyclists that experienced knee problems over the course of the study and the relatively high average prevalence of substantial knee problems. The reported extent to which lower back pain is a problem for elite cyclists varies between studies. We have previously conducted a cross-sectional study in which 58% of professional male cyclists reported having experienced lower back pain in the previous 12 months, with 41% reported having sought outpatient medical assistance for it (Clarsen et al., 2010). While the results of the current study give a slightly more conservative estimation of the extent of the problem, the fact that the average prevalence of substantial lower back problems was at least double that of the other sports lends support to our previous conclusion that lower back pain among elite road cyclists is a problem that warrants research attention.

Despite the limited amount of research into floorball injuries, three prospective cohort studies have been conducted and all report a relatively low rate of overuse problems (Wikstrom & Andersson, 1997; Snellman et al., 2001; Pasanen et al., 2008). In contrast, we found a high prevalence of overuse problems in the knee, lower back, and shoulder among floorball players. Closer inspection of our data reveals that a vast majority of the overuse problems reported had little consequence on players' participation or performance, reflected in the low prevalence of substantial overuse problems. However, because of the high prevalence of minor problems over the duration of the project, the overall impact of overuse problems was relatively high compared with other sports, particularly in the lower back and knee.

Epidemiological studies of handball players have largely focussed on acute injuries, with few reporting the rate of overuse complaints. However, several prospective cohort studies have found a moderate rate of overuse knee and shoulder injury despite having used a time-loss definition (Nielsen & Yde, 1988; Seil et al., 1998; Møller et al., 2012), and two cross-sectional studies have reported a high prevalence of overuse shoulder complaints among elite players (Gohlke et al., 1993; Myklebust et al., 2013). In the current study, the rate of knee and shoulder problems was high among the handball players, with an average prevalence of 20% and 22%, respectively. As both areas were among the problems representing the greatest overall impact on athletes in this study, future efforts toward their prevention are warranted.

A high prevalence of overuse knee injuries is well documented among volleyball players (Lian et al., 2005; Bahr, 2009). Our results strongly support this, being the area with the highest recorded prevalence of overuse problems and of substantial overuse problems. The shoulder and lower back are also reported to be common sites of overuse injury in volleyball (Wang & Cochrane, 2001; Bahr & Reeser, 2003; Verhagen et al., 2004; Bahr, 2009; Reeser et al., 2010). In the current study, we found a relatively high prevalence of shoulder complaints and it is worth noting that the prevalence of substantial shoulder problems was comparable to the handball players. In contrast, the prevalence of lower back problems was low among the volleyball players in this study.

This study uses a newly designed method for recording overuse problems based on direct reporting from athletes. This approach allows for the use of a broad, "all physical complaints" definition without the systematic bias that could be expected if third-party injury recorders, such as team medical staff, were used to record injuries (Orchard & Hoskins, 2007). Therefore, this study is perhaps the first to make valid and reliable comparisons of the rate of overuse problems across a variety of different sports. Two methods of comparison were used: GEE and relative impact. The main benefit of using GEE is that, as repeated measures are accounted for, changes in injury prevalence can be assessed over time. In contrast, the relative impact score is a more crude summary measure, which does not account for change over time or confounding. However, it is easy to calculate, takes into account all available data on the consequences of overuse injuries, and allows for comparisons between and within sports that are relatively easy to communicate. For example, among the volleyball players in the current study, the impact of knee problems was more than six times greater than the impact of lower back problems. Similarly, the impact of lower back problems was more than three times greater in cycling than in cross-country skiing.

One of the major strengths of this study is that the response rate to the weekly questionnaires was very high, ranging from 91% to 98% across the five sports. Furthermore, the effects of missing questionnaire data were analyzed and MI techniques were used to estimate the studied relationships. We recommend that studies using similar methods employ this approach where possible, as it allows for the inclusion of all athletes' questionnaire data in statistical analyses, rather than only those with complete responses. This latter method is most frequently used but has proven to give severely biased results (Eekhout et al., 2012). As a minimum standard, studies should report their missing data rate thoroughly and comment on the reasons and likely impact of missing questionnaire responses on the validity of injury data (von Elm et al., 2007; Sterne et al., 2009).

It must be recognized that this study has several limitations. Firstly, as the design requires that a limited number of areas of interest be defined *a priori*, it does not give a complete picture of the extent of overuse injury in the five sports. For example, anterior tibial pain is reported to be common in handball and floorball (Pasanen et al., 2008; Møller et al., 2012), but was not registered in this study. As these data were originally collected in order to test and validate the new surveillance method, we chose to include areas that are generally regarded to be common sites of overuse sporting injury. The exception was to include questions on the anterior thigh for the skiers and cyclists, as we saw this as an opportunity to document a potentially important problem for the first time. However, in future studies using these methods, we recommend that the choice of areas to include should be based on previous research, the opinion of key stakeholders in the sport and thorough pilot testing.

A second limitation is that we did not record specific diagnoses for the overuse problems that athletes reported. While this is possible and has been done in other studies using similar methods (Clarsen et al., 2014), close follow-up from medical staff is required for the duration of the data collection period and this was beyond the scope of the current study. Instead, we conducted telephone interviews at the study's conclusion; an approach limited by recall bias and by athletes' lack of medical expertise. Using this method, we felt confident to categorize problems into overuse and acute injuries, but did not trust that athletes could provide us with a reliable diagnosis themselves.

Another limitation to this study is that comparisons have been made between groups of athletes with large differences in their demographic characteristics. As shown in Table 3, in certain cases, athlete characteristics such as sex and body mass were significantly associated with injury outcomes. Even in cases where statistical significance was not found, demographic characteristics were found to have a confounding effect on comparisons of injury prevalence between sports. We therefore recommend that future studies aiming to compare groups of athletes using these methods should make every effort to ensure baseline comparability of athletes' demographic characteristics and use multivariable models that adjust for their effects.

It is also of interest to note that the prevalence of overuse problems fell over the duration of the study in every sport across all anatomical regions. As data collection occurred at slightly different times for each sport and thus the part of the season in which data were collected varied, it is unlikely that this represented a true phenomenon. Instead, we suspect that athletes' threshold for reporting minor problems increased over the course of the study because of so-called "respondent fatigue" (Ben-Nun, 2008) In contrast, the prevalence of substantial overuse problems was much more stable throughout the course of the study in all areas. This has implications for the interpretation of data from future studies using these methods.

A final limitation to this study is the variation in the extent to which each group can be considered representative of all elite Norwegian athletes from that sport. For example, the cohort of cyclists included almost every elite-level cyclist in the country, whereas the floorball and handball players came from a single club and may not be representative of all elite-level players in Norway. Furthermore, it is important to note that this study was only conducted over 3 months and therefore does not account for potential variations in injury prevalence over the entire season. Ideally, studies using this design should include large numbers of subjects and encompass at least one whole season or calendar year.

Perspectives

This paper reports the prevalence and impact of overuse injuries in cross-country skiing, cycling, floorball, handball, and volleyball. Previous injury studies of these sports have used methods poorly suited to prospective recording of overuse injuries, whereas in this study, we used a new method specifically designed for such a purpose. Our data may therefore represent a more valid picture of the extent of overuse injuries in these sports, and help guide the direction of future injury prevention research. Particular focus should be placed on those areas with the greatest impact, such as the knee in volleyball, the knee and shoulder in handball, the knee and lower back in floorball, and the knee in cycling.

This paper also demonstrates how groups of athletes can be compared using the Oslo Sports Trauma Research Center method of recording overuse injuries. Missing data is an important factor to consider when these techniques are used and MI techniques should be considered. This has implications for future studies using these methods of data collection, particularly in risk factor studies and injury prevention trials.

Key words: Epidemiology, cross-country skiing, cycling, floorball, handball, volleyball.

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Paper III

Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study

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ABSTRACT

Aim To determine whether rotator cuff strength, glenohumeral joint range of motion and scapular control are associated with shoulder injuries among elite male handball players.

Methods A total of 206 players in the Norwegian elite handball league for men were tested prior to the 2011–2012 season. Measures included: (1) glenohumeral internal and external rotation range of motion, (2) isometric internal rotation, external rotation and abduction strength and (3) assessment of scapular dyskinesis. Players were followed prospectively for the entire regular season (30 weeks), with shoulder problems registered bi-weekly using the Oslo Sports Trauma Research Center Overuse Injury Questionnaire. A cumulative severity score was calculated for each player based on their questionnaire responses. This was used as the outcome measure in risk factor analyses.

Results The average prevalence of shoulder problems throughout the season was 28% (95% CI 25% to 31%). The prevalence of substantial shoulder problems, defined as those leading to moderate or severe reductions in handball participation or performance, or to time loss, was 12% (95% CI 11% to 13%). Significant associations were found between obvious scapular dyskinesis (OR 8.41, 95% CI 1.47 to 48.1, $p<0.05$), total rotational motion (OR 0.77 per 5° change, 95% CI 0.56 to 0.995, $p<0.05$) and external rotation strength (OR 0.71 per 10 Nm change, 95% CI 0.44 to 0.99, $p<0.05$) and shoulder injury.

Conclusions Injury prevention programmes should incorporate interventions aimed at improving glenohumeral rotational range of motion, external rotation strength and scapular control.

INTRODUCTION

Handball is a sport which places large demands on players' shoulders due to a high volume of throwing, as well as frequent physical contact. Cross-sectional studies suggest that shoulder injuries are common among elite players.[1 2] However, as players often continue to train and compete despite the existence of overuse shoulder injuries,[1 3] prospective cohort studies of handball injuries which have used a time-loss injury definition are unlikely to have captured the true extent of the problem.[4–6]

We recently conducted a prospective study of overuse injuries among athletes from five different sports, including handball, using a new method designed specifically to record overuse problems.[3] We found that shoulder problems among handball players was one of the injury areas with the greatest impact on sports participation and performance. However, the study involved a limited sample and lasted only 3 months. Therefore, the extent and severity of shoulder injuries in elite players during a full competitive season remains unknown.

Several studies have investigated risk factors for shoulder injuries among overhead athletes, with particular focus on glenohumeral joint range of motion (ROM)[7–12] and shoulder strength.[12–14] While a majority of studies have been on baseball pitchers, these factors have also been linked to injury among handball players.[8 13] Scapular control impairment, referred to as scapular dyskinesis, is also a commonly proposed risk factor despite a lack of evidence linking it to shoulder injury.[15–17]

The main objectives of this study were to record the prevalence of shoulder problems among elite male handball players over a full competitive season, and to investigate the relationship between shoulder ROM, isometric strength and scapular dyskinesis and shoulder injury. This information is necessary to inform the development of injury prevention interventions.

METHODS

Study design

This was a prospective cohort study involving all teams in the Norwegian elite handball series for men (Postenliga) in the season 2011–2012. We visited each team during a training session in 4 weeks prior to the season and every player present at the session was invited into the study. Players were eligible for participation if they had a contract with a Postenliga club in the season 2011–2012 (N=230), irrespective of whether they had current or previous shoulder pain/injury. All players who consented to participation performed baseline testing and were followed for the duration of the season (September 2011 to May 2012), during which time the extent to which they experienced shoulder problems was monitored bi-weekly using the Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire. Written consent was obtained from all participants.

Baseline testing

Fahlström questionnaire

Each player's shoulder injury history and status at the time of testing was assessed using a modified version of the Fahlström questionnaire previously used in studies of elite handball players.[1] Each player was also asked whether they had ever undergone shoulder surgery.

Range of motion

Internal rotation (IR) and external rotation (ER) ROM was measured at the glenohumeral joint using a digital inclinometer attached to a 30 cm Perspex ruler (Acumar digital inclinometer, Lafayette Instrument, Lafayette Indiana, USA) with the player in supine with their shoulder abducted to 90°. When necessary, a folded towel was used to ensure that the upper arm was correctly aligned in the frontal plane. The scapula was stabilised by the examiner with their thumb on the coracoid process and four fingers grasping the spine of the scapula posteriorly.[18] The end of IR and ER ROM was defined as the point at which the scapula was felt to move. The averages of two repeated measures were recorded as the participant's values for IR and ER. These values were summed to give the total rotational motion (TROM).

Isometric strength

Isometric IR, ER and abduction strength was measured using a digital handheld dynamometer (MicroFET, Hoggan Health Industries, Salt Lake City, Utah, USA). IR and ER strength was measured with the participant in supine with their shoulder in neutral position and their elbow flexed to 90°. Abduction strength was measured with the participant standing with their shoulder in ER and abducted to 30° in the plane of the scapula. Their elbow was extended in a neutral 'open can' position. We verbally and manually assisted players to stabilise their scapula prior to initiating abduction. However, no external scapula fixation was provided during actual testing. Players were asked to perform all strength measures twice and the best attempt was recorded. A detailed protocol of ROM and strength testing is available as an online supplementary appendix.

Scapular control

A physiotherapist observed players perform five repetitions of flexion and abduction while holding a 5 kg weight. Each shoulder was rated as having normal scapular control, slight scapular dyskinesis or obvious dyskinesis, according to the methods proposed by McClure *et al*.[19] All assessments were performed by the same physiotherapist, who made their rating based on live observation and, if necessary, inspection of recordings made by a video camera situated 3 m behind the player.

Reliability of shoulder tests

Strength and ROM testing was performed by two physiotherapists, each of whom tested six teams. Each test's inter-rater reliability was determined using a pilot study of 38 shoulders which were measured in a randomised order by both physiotherapists, blinded to the results of each other. As all ROM and strength measures were performed twice during actual player testing, the two measures were used to assess intra-rater reliability. For scapular dyskinesis testing, intra-rater reliability was determined using 30 anonymised videos which were viewed in a randomised order and rated by the tester on two occasions separated by 1 week.

Injury registration

The OSTRC Overuse Injury Questionnaire was emailed to all players in the project every second Sunday for the entire regular season using online survey software (Questback V. 9692, Questback AS, Oslo, Norway). Questions included the extent to which shoulder problems affected the player's participation, training volume and performance, as well as the extent to which he had experienced shoulder pain over the previous 7 days.[20] Players were asked about their dominant and non-dominant shoulders separately, with shoulder problems defined as any pain, ache, stiffness, instability, looseness or other complaints related the shoulder. The survey software prevented questionnaire submission if all items were not fully completed and automatically sent reminder emails to non-responders after 3 and 7 days.

The prevalence of shoulder problems was calculated for the dominant and the non-dominant shoulder each time the questionnaire was administered by dividing the number of players who reported any problem (ie, anything but the minimum value in any of the four questions) by the number of questionnaire respondents. At the end of the study, the average prevalence of shoulder problems was calculated for each shoulder.

The average prevalence of *substantial* shoulder problems was also calculated and expressed for each shoulder in the same way as described above. However, the numerator in the prevalence calculations only included shoulder problems leading to moderate or severe reductions in training volume or sporting performance, or a total inability to participate.[20] This filtered out problems with little functional consequences.

Each time a player responded to a questionnaire, their responses enabled the calculation of a severity score ranging from 0 to 100.[20] At the conclusion of the study, each player's scores were summed and divided by their number of questionnaire responses to determine their average severity score. This was used as the outcome measure in risk factor analyses, as described below.

Statistical methods

Players with fewer than four questionnaire responses were excluded from all analyses due to insufficient data. As average severity scores were heavily skewed in the positive direction they were dichotomised using a cut-off value of 40 to distinguish 'injured' from 'uninjured' players. This value was chosen as it indicates that the player had substantial shoulder problems throughout the season. Post hoc Receiver Operator Characteristic curve analyses confirmed that this value had the greatest predictive ability to identify significant risk factors.

We considered accounting for clustering of data by teams in the statistical methods. However, the variance between teams was estimated to be zero. Therefore, associations between risk factors and shoulder injury were assessed using normal multivariable logistic regression models. The following were analysed as potential risk factors: obvious scapular dyskinesis, slight or obvious scapular dyskinesis, IR strength, ER strength, ratio of ER to IR strength, IR ROM, ER ROM, TROM, >5° TROM difference between shoulders, <5° ER gain in the dominant shoulder (ER deficit) and glenohumeral IR deficits of 5°, 10°, 15° and 20°. Strength measures were adjusted for body mass and demographic variables possibly associated to shoulder injury ($p<0.2$) were added to each model using a forward selection procedure.

We compared dominant and non-dominant shoulder strength and ROM using paired-samples t tests and Wilcoxon's rank-sum test. Associations between participant characteristics and data completeness were analysed using logistic regression. The reliability of the ROM and strength tests was assessed by calculating the intraclass correlation coefficient (ICC), using a two-way mixed model (absolute agreement) for inter-rater reliability and a two-way random model (absolute agreement) for intra-rater reliability.[21] The intra-rater reliability of scapular dyskinesis testing was assessed using Spearman's r (R_S).

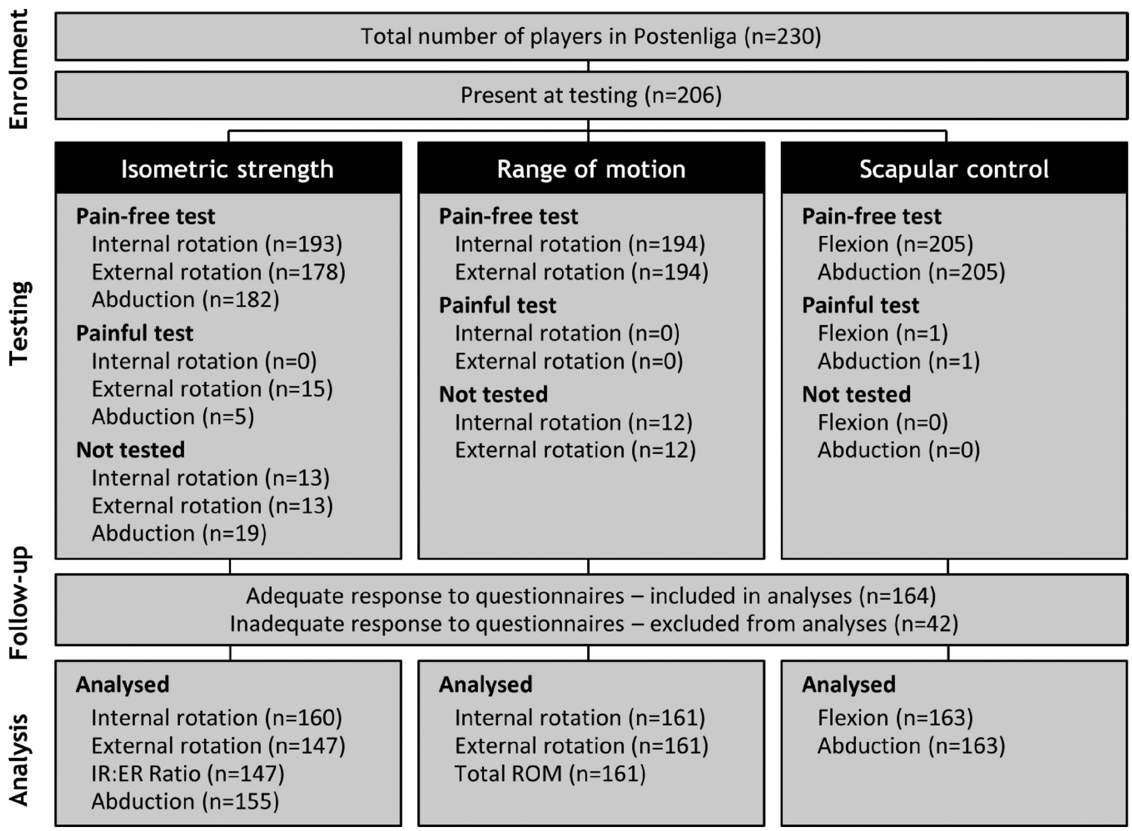

Figure 1 Study flow chart showing the number of players included, tested and analysed (ER, external rotation; IR, internal rotation; ROM, range of motion).

RESULTS

Participants

A total of 206 of 230 Postenliga players agreed to participate in the study (90%). On average, players were 24 years old (SD 4, range 18–48), 189 cm tall (SD 7, range 167–207) and weighed 89 kg (SD 10, range 64–114). They had been playing handball for an average of 14 years (SD 5, range 4–34) and had played in the elite series for an average of 4 years (SD 4, range 0–15). A majority of players were right handed (73%). Eighty-six were back players (42%), 48 were wing players (23%), 30 were line players (15%), 29 were goalkeepers (14%) and 15 played in a combination of positions (6%). All participants completed the baseline questionnaire. The number that was tested and included in each analysis is shown in figure 1.

Fahlström questionnaire

At the time of testing, 154 players (75%) reported a history of shoulder pain associated with handball. Sixty-five players (32%) reported current shoulder pain and 44 players (21%) reported having to modify their training or match participation due to pain. Of these, 23 (11%) were currently unable to play matches due to shoulder pain, 12 had difficulties in normal daily activities (6%) and 9 had sleep disturbances due to pain (4%). Seven players (3%) had undergone shoulder surgery.

Shoulder testing

Range of motion

Dominant shoulders had significantly less IR than their non-dominant shoulders (mean difference: 4°, 95% CI 3 to 5°, $p<0.01$), with eight players having greater than 20° glenohumeral IR deficit. Dominant shoulders also had a greater ER range (mean difference: 6°, 95% CI 5 to 8°, $p<0.01$) and a significant increase in TROM (mean difference: 3°, 95% CI 1 to 4°, $p<0.01$; figure 2). Eighty-seven players had <5° ER gain in their dominant shoulder (ER deficit), and 19 players had a TROM difference of more than 5° between sides.

Isometric strength

Compared with the non-dominant shoulders, dominant shoulders were significantly weaker in ER (mean difference: 0.09 Nm/kg, 95% CI 0.04 to 0.13, $p<0.01$) and stronger in abduction (mean difference: 0.07 Nm/kg, 95% CI 0.2 to 1.2, $p<0.01$). The ratio of ER to IR was lower for dominant shoulders (mean difference: 4%, 95% CI 2 to 6%, $p<0.01$; figure 3).

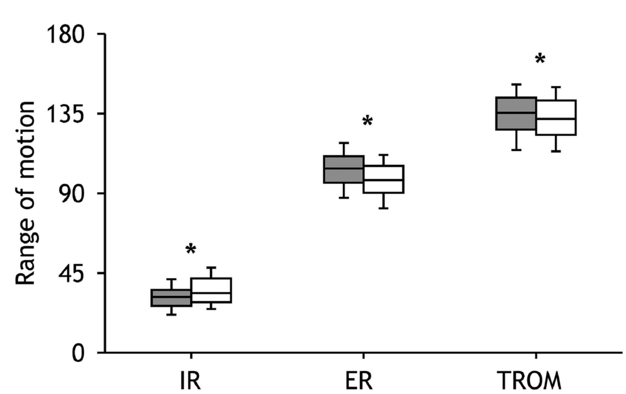

Figure 2 Range of motion differences between dominant shoulders (grey boxes) and non-dominant shoulders (white boxes; ER, external rotation; IR, internal rotation; TROM, total rotational motion; *$p<0.05$).

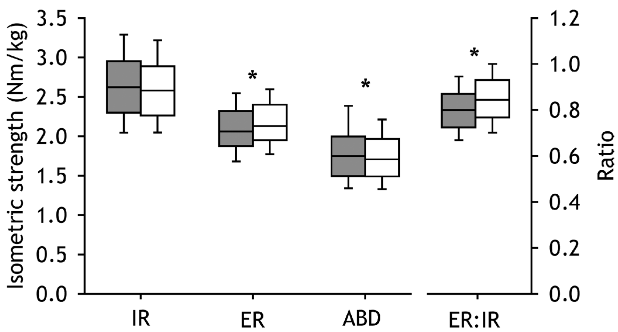

Figure 3 Isometric strength differences between dominant shoulders (grey boxes) and non-dominant shoulders (white boxes). ABD, abduction; ER, external rotation; IR, internal rotation; *p<0.05.

Scapular control

A total of 86 players (42%) were rated as having slight scapular dyskinesis in their dominant shoulders during flexion and 44 (21%) during abduction. Fourteen players (7%) were rated as having obvious scapular dyskinesis in their dominant shoulders during flexion and five (2%) in abduction.

Reliability of shoulder tests

The inter-rater and intra-rater reliability (ICC) of ROM and strength tests is shown in table 1. For classification of scapular control into three groups (normal, slight or obvious dyskinesis) the intra-rater reliability (R_S) was 0.78 for flexion and 0.69 for abduction. For classification into two groups (normal or abnormal) the R_S was 0.76 for flexion and 0.69 for abduction.

Prospective monitoring of shoulder problems

The OSTRC Overuse Injury Questionnaire was administered 15 times during the course of the season and the total response rate was 63%. Complete data were collected from 25% of players, 53% of players completed 10 or more questionnaires and 80% of players completed four or more. The response rate varied from 40% to 81% between teams. However, no other demographic characteristics were associated with missing data and there were no associations between players' baseline shoulder status or injury history and data completeness.

One hundred and eight players (52%) reported problems in their dominant shoulder at some point during the season. Of these, 15 players only reported mild pain with no functional consequences and 50 players reported problems causing moderate or severe reductions in participation or performance (defined as *substantial* problems). Fifty-five players (27%) reported problems in their non-dominant shoulders during the season, 7 of which only involved mild pain and 14 of which were substantial problems.

The average prevalence of shoulder problems during the season was 28% (95% CI 25% to 31%) in the dominant shoulder and 7% (95% CI 6% to 9%) in the non-dominant shoulder. The average prevalence of *substantial* shoulder problems was 12% (95% CI 11% to 13%) in the dominant shoulder and 1% (95% CI 0.7% to 1.3%) in the non-dominant shoulder.

Table 1 ICC for measures of strength and ROM

	Inter-rater		Intrarater	
	ICC	(95% CI)	ICC	(95% CI)
ROM				
IR	0.65	(0.31 to 0.82)	0.99	(0.98 to 0.99)
ER	0.88	(0.76 to 0.94)	0.98	(0.98 to 0.99)
Strength				
IR	0.87	(0.75 to 0.93)	0.86	(0.81 to 0.89)
ER	0.86	(0.72 to 0.93)	0.80	(0.74 to 0.85)
Abd	0.91	(0.82 to 0.95)	0.83	(0.77 to 0.88)

Abd, abduction; ER, external rotation; ICC, intraclass correlation coefficients; IR, internal rotation; ROM, range of motion.

Risk factor analyses

Demographic factors

A history of shoulder surgery (OR 8.3, 95% CI 1.3 to 51.4, p=0.02) and playing in a back position (OR 16.4, 95% CI 2.0 to 132.3, p<0.01) were significantly associated with average severity scores. No associations were identified between players' average severity scores and their age, height, body mass, years of handball participation, years of participation at an elite level or their team.

Shoulder tests

Obvious scapular dyskinesis, reduced TROM and isometric ER weakness were significantly associated with average severity scores (figure 4). As shown in the figure, slight scapular dyskinesis (p=0.09), IR ROM (p=0.19), supraspinatus strength (0.08) and the ratio of ER to IR strength (p=0.13) failed to achieve statistical significance. No associations were found between average severity scores and glenohumeral IR deficits, ER deficits or the difference in TROM between sides.

DISCUSSION

This is the first prospective cohort study on risk factors for shoulder injuries among elite male handball players. The prevalence of shoulder problems was high, and we identified several internal risk factors associated with shoulder injury. In particular, players with obvious scapular dyskinesis, reduced ER strength and reduced TROM had a higher probability of experiencing substantial shoulder problems throughout the season.

Our surveillance data support previous epidemiological studies that have found shoulder problems to be common in handball. This has been found in investigations of various player populations, using a variety of study designs and measurement methods.[1 3 6] In the current study, we used a new surveillance method designed specifically to capture overuse problems in sport.[20] The prevalence of all shoulder problems and of substantial problems was among the highest we have measured in any anatomical area in any sport using these methods.[3 22] This is obviously an injury problem that warrants preventative efforts. The results of our risk factor analyses may provide guidance in the development of prevention programmes.

Glenohumeral ROM and shoulder injury

Reductions in IR and increases in ER have been demonstrated in the dominant shoulders of uninjured overhead athletes from a variety of sports.[1 7 8 12 23–26] This is regarded as a normal soft tissue and/or bony adaptation to the repeated throwing,[15] which may even be protective against injury.[27] However, several studies have linked large differences in IR and TROM between dominant and non-dominant shoulders to throwing-related shoulder injuries.[7–11] For example, Wilk *et al*[7] found that glenohumeral IR deficits of more than 20° and TROM differences exceeding 5° between shoulders were significant risk factors for injury among baseball pitchers. The same group has also recently proposed that ER deficits may also be an important risk factor.[24] In

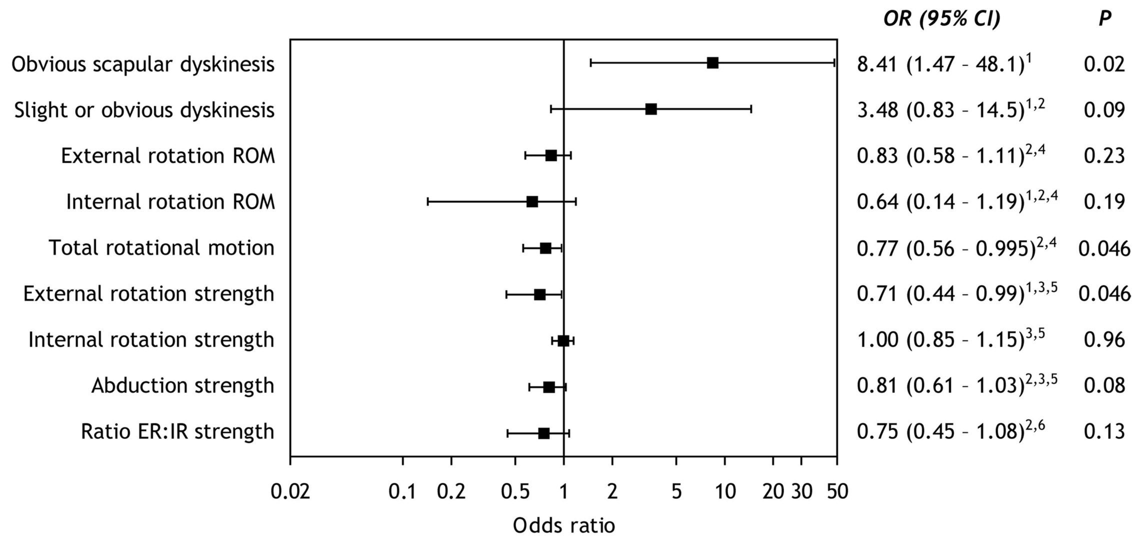

Figure 4 ORs and 95% CIs for associations between risk factors and substantial shoulder problems (average severity score >40) based on multivariable logistic regression analyses adjusted for [1]player position (back player), [2]history of shoulder surgery and [3]body mass. Expressed per [4]5° change, [5]10 Nm change, [6]5% change. ER, external rotation; IR, internal rotation; ROM, range of motion.

the current study, dominant shoulders demonstrated a small but significant reduction in IR, an increase in ER and an increase in TROM compared with non-dominant shoulders. However, we were unable to find any associations between glenohumeral IR deficits, ER deficits or TROM differences and injury, despite using a range of cut-off values to define these terms.

Our TROM measures were approximately 40° lower than those reported for baseball pitchers.[24] Although this might be due to differences in measurement technique, other studies of handball players,[1 8] as well as of tennis,[26] volleyball[25] and badminton players[28] report similar values. Handball players throw with wide variety or overarm and underarm techniques and their shoulders are frequently exposed to contact and blocking while in an elevated position. This may affect their ROM profiles and explain why concepts and criteria developed for pitchers, such as glenohumeral IR deficit, were not identified as risk factors in the current study.

In this study, absolute rather than relative TROM values were significantly associated with shoulder problems. This suggests stretching should be considered in the development of injury prevention programmes.

Rotator cuff strength and shoulder injury

We found a significant association between ER weakness and an increased probability of substantial shoulder problems throughout the season. There was no association between IR strength and injury. However, non-significant trends in the data suggest that lower ER to IR ratios and abduction strength may also be noteworthy risk factors.

Similar findings have been reported in studies of baseball pitchers, where isometric ER, abduction and ER to IR ratio have been associated with shoulder injury.[12 14]

Among female youth handball players, Edouard *et al*[13] found no association between isokinetic ER or IR strength and injury. However, players with low ratios of concentric ER to concentric IR strength, and high ratios of eccentric IR to concentric ER strength had an increased risk of injury. As a different method was used to measure strength, their results cannot be directly compared with the current study. Nevertheless, the two studies can be interpreted in a similar way, as both suggest that ER strengthening exercises may be important in injury prevention programmes.

Scapular dyskinesis and shoulder injury

Scapular dyskinesis is a common finding among people with shoulder pain and a variety of shoulder pathologies such as impingement syndrome, rotator cuff tears, glenoid labrum tears and instability.[16] It has also been shown to be common among athletes from a variety of overhead sports, such as baseball, swimming and tennis.[29–31] However, it is common among symptom-free athletes as well as those with pain, and evidence of an association between scapular dyskinesis and shoulder symptoms among overhead athletes is lacking.[32–35] A significant association has been demonstrated among rugby players,[36] but as the mechanism of shoulder injury in rugby differs greatly from throwing sports such as handball the implications of this finding to the current study are unclear. In contrast to previous studies of overhead athletes, we may have been able to demonstrate a relationship due to a sufficient number of players being included in the study, and because the outcome measure was sufficiently sensitive to detect those with the greatest amount of shoulder problems.

Although we were able to demonstrate a significant, robust association between obvious scapular dyskinesis and shoulder problems, the size of the relationship is unclear. This is reflected in the width of the OR CI. Studies involving larger numbers of players are necessary to determine this with greater accuracy. Nevertheless, this study clearly indicates that injury prevention programmes for shoulder injuries in handball should include exercises to improve scapular control.

Methodological considerations

The major strengths of this study were that we used a prospective cohort design and included a large, representative sample of elite male handball players. We also used sensitive injury surveillance methods that capture all physical complaints. This proved necessary despite shoulder problems being highly prevalent, as few cases satisfied the time-loss injury definition most commonly used in surveillance studies.[37] However, this study also has several limitations which should be considered when interpreting its results.

The challenge of overuse injuries

Traditionally, risk factor studies exclude injured players from baseline testing and record newly incurred injuries throughout the study. This temporal sequence allows for an assumption of cause and effect between risk factors and injury. However, challenges exist when applying this model to the study of overuse and chronic injuries, such as in the current study. First, a large proportion of players reported having shoulder problems at the time of testing. Excluding them would have biased the cohort such that it would not have been a representative sample. Therefore, only players who experienced pain during actual testing were excluded from analyses. Second, the majority of cases reported during this study represented chronic problems, with only a few minor cases occurring for the first time. Therefore, this study is limited to assessing associations between risk factors and shoulder problems and causation cannot be assumed.

Test selection

As with all risk factor studies, a key limitation of this study is the choice of screening tests and measurement techniques. In order to maximise clinical relevance, we chose simple and inexpensive testing in the field rather than in our biomechanics laboratory. The reliability of the tests ranged from moderate to very high, but in certain cases their validity could be questioned. Strength tests were isometric rather than dynamic, and for IR and ER they were performed in a supine position with the shoulder in neutral. This position has previously been shown to be reliable,[21] and was selected based on a pilot study where we found that testing strength in an elevated position provoked pain in a greater number of players. However, the degree to which isometric testing in this position relates to dynamic shoulder strength during overhead throwing is unknown.

For ROM measurement, we used a single tester with a digital inclinometer rather than two testers with a bubble goniometer, as commonly described. Both methods have been shown to be reliable,[21] but their results may differ systematically.[38 39] Therefore, the absolute ROM values reported in this study may not be directly comparable to previous research.

For scapular dyskinesis, we used a subjective criterion-based assessment as recommended in a recent consensus statement.[16] We chose a method with three rating options which has been shown to be valid for assessing three-dimensional scapular motion in overhead athletes.[19 33] However, it has been suggested that a two-option rating (normal or abnormal) is more reliable than when multiple criteria are used.[40] In this study, there was no improvement in intra-rater reliability when a two-option classification was applied. A strength of this study is that we used only one rater to assess scapular dyskinesis, as inter-rater reliability has been found to be moderate to low.[40 41]

We also chose to focus only on local risk factors at the shoulder rather than the entire kinetic chain, which is often implicated in throwing injuries.[15] It is possible that factors such as hip and trunk rotation are associated with shoulder injuries in handball, and kinetic chain exercises should probably be considered in future injury prevention programmes. However, testing these factors was beyond the scope of this study.

Diagnostic accuracy

A second limitation to this study is that we have monitored self-reported shoulder problems and lack detailed diagnostic information on each case. Shoulder pain and dysfunction in throwers may have many causes, such as tendon pathology, subacromial and internal impingement, glenoid labrum injuries, glenohumeral joint instability and acromioclavicular joint dysfunction.[27 42] The risk factors for each of these conditions may be different. Furthermore, several cases in this study were acute flare-ups of chronic problems or long-term problems initially caused by an acute trauma. Separation of the database into acute and overuse injuries according to current definitions was therefore particularly difficult, and no attempt was made to do so. As a result, it is likely that some injuries are included that were purely caused by acute trauma. This may have reduced our ability to identify relationships between risk factors and non-traumatic shoulder injuries.

Missing data

This study's third limitation is that the response rate was limited, especially compared with previous studies using similar surveillance methods.[3 22 43] Based on players' injury history and baseline status, it seems unlikely that there were systematic differences between responders and non-responders. However, the degree to which non-responders experienced shoulder problems during the course of the season remains unknown. The extent of missing data prevented us from using multiple imputation to estimate missing values and from using longitudinal statistical methods. Despite this, we felt that the existing data enabled us to identify players with the greatest amount of shoulder problems throughout the season, which was the main objective of surveillance.

Nevertheless, 42 athletes had to be excluded from analyses due to insufficient data, which reduced the statistical power of the study. This may have affected the accuracy of our coefficient estimates and prevented us from detecting other risk factors.

CONCLUSION

Shoulder injuries are highly prevalent among elite male handball players and preventative efforts are warranted. This study identified a number of internal modifiable risk factors associated with substantial shoulder problems, including TROM, ER strength and scapular dyskinesis. Injury prevention programmes incorporating these factors should be tested using randomised controlled trials.

What are the new findings?

- Shoulder injuries are highly prevalent among elite male handball players.
- Obvious scapular dyskinesis, reduced total range of motion and reduced external rotation strength are associated with an increased probability of shoulder injury.

How might it impact on clinical practice in the near future?

Programmes aimed at preventing shoulder injuries in handball should incorporate exercise to improve total rotational motion, external rotation strength and scapular control.

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Contributors RB, SHA, RM and GM contributed to project planning, data collection and manuscript preparation. BC was responsible for data analysis also for the overall content as the guarantor.

Competing interests None.

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Paper IV

The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite athletes

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ABSTRACT

Background Little information exists on the illness and injury patterns of athletes preparing for the Olympic and Paralympic Games. Among the possible explanations for the current lack of knowledge are the methodological challenges faced in conducting prospective studies of large, heterogeneous groups of athletes, particularly when overuse injuries and illnesses are of concern.
Objective To describe a new surveillance method that is capable of recording all types of health problems and to use it to study the illness and injury patterns of Norwegian athletes preparing for the 2012 Olympic and Paralympic Games.
Methods A total of 142 athletes were monitored over a 40-week period using a weekly online questionnaire on health problems. Team medical personnel were used to classify and diagnose all reported complaints.
Results A total of 617 health problems were registered during the project, including 329 illnesses and 288 injuries. At any given time, 36% of athletes had health problems (95% CI 34% to 38%) and 15% of athletes (95% CI 14% to 16%) had substantial problems, defined as those leading to moderate or severe reductions in sports performance or participation, or time loss. Overuse injuries represented 49% of the total burden of health problems, measured as the cumulative severity score, compared to illness (36%) and acute injuries (13%).
Conclusions The new method was sensitive and valid in documenting the pattern of acute injuries, overuse injuries and illnesses in a large, heterogeneous group of athletes preparing for the Olympic and Paralympic Games.

INTRODUCTION

In recent years, the value of regular monitoring in protecting the health of athletes has received increasing recognition.[1 2] The International Olympic Committee, together with several major International Federations and National Olympic Committees, has developed a surveillance system designed to record injuries and illnesses in major championships,[3] and this has been successfully implemented in several Olympic Games, World Championships and other major sporting tournaments.[4–11] Similarly, the International Paralympic Committee has conducted systematic injury surveillance at the 2002, 2006 and 2010 Winter Paralympic Games.[12–14] However, with the exception of certain sports such as football,[15] there are few prospective studies of health problems among Olympic-level athletes outside of the brief period in which they are competing in major championships. Little is known, therefore, about their patterns of illness and injury in their normal training and preparation phases.

Among the possible explanations for this lack of knowledge are the methodological challenges faced when conducting longer term studies in this group of athletes. The methods currently employed in a majority of prospective surveillance studies are based on those developed for recording football injuries,[16] and while they may work well for team sports, they are difficult to implement among groups of individual athletes or those without a centralised team structure.[17] Standard methods of injury surveillance may also be poorly suited to collecting information on overuse conditions, which represent the predominant injury type in many Olympic sports.[10 18–20] We have recently discussed these limitations in detail,[21] made general recommendations for more appropriate methodology[21] and developed new tools that are better suited to the study of overuse injuries.[22]

Our first aim in the present study was therefore to modify our new method[22] such that it can be used to record not only overuse injuries but also all types of health problems in studies of large, heterogeneous groups of athletes. Our second aim was to apply the method to analyse the patterns of illness and injury in the Norwegian Olympic and Paralympic teams during their preparations for the 2012 games in London.

METHODS

Recruitment

During the summer of 2011, the coaches of the Norwegian national teams in all candidate sports for the London Olympic or Paralympic Games were asked to provide a list of athletes who had the potential to qualify. The final list included 143 athletes, 142 of whom gave their consent to participate in the project. This included 116 Olympic candidates (54 male and 62 female) and 26 Paralympic candidates (15 male and 11 female). The Olympic sports in the study included archery (n=1), athletics (n=22), beach volleyball (n=6), boxing (n=2), cycling (n=12), handball (n=24), kayak (n=7), rowing (n=13), sailing (n=8), shooting (n=5), swimming (n=10), taekwondo (n=3), weightlifting (n=1) and wrestling (n=2). The Paralympic sports included archery (n=1), athletics (n=1), boccia (n=1), cycling (n=2), equestrian (n=4), sailing (n=4), shooting (n=7), swimming (n=3) and table tennis (n=3). The medical personnel that participated in classifying and diagnosing illness and injuries included all the

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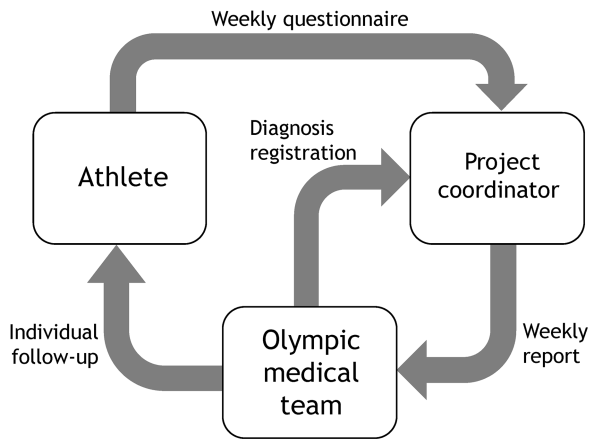

Figure 1 Diagram showing the procedures used to collect data on health problems.

doctors (n=7) and physiotherapists (n=13) who were selected to travel with the Norwegian athletes to the Olympic or Paralympic Games. The study was approved by the Norwegian Data Inspectorate and reviewed by the South-Eastern Norway Regional Committee for Research Ethics. Informed consent was obtained from the athletes at the first registration.

Data collection procedure

Every Sunday for the duration of the project, we used online survey software (Questback V.9692, Questback AS, Oslo, Norway) to send all athletes an email linking them to an internet-based questionnaire on health problems, with an automatic reminder email 3 days later if needed (figure 1). Each Thursday, the project coordinator (BMC) compiled a report based on the questionnaire responses from that week and sent it to the relevant team medical staff. They were then expected to follow-up each case and, in addition to providing normal clinical management or advice to the athlete, to fill in a report classifying the type and diagnosis of each health problem. These reports were sent back to the project coordinator on a monthly basis.

The Oslo Sports Trauma Research Center (OSTRC) questionnaire on health problems

We developed the Oslo Sports Trauma Research Center (OSTRC) Questionnaire on Health Problems based on the OSTRC Overuse Injury Questionnaire.[22] The four key questions on the consequences of health problems on sports participation, training volume and sports performance as well as the degree to which they have experienced symptoms were modified to capture all types of health problems including illness and acute injuries (figure 2). If the athlete answered the minimum score for each of these questions (full participation without problems/ no training reduction/no performance reduction/no symptoms), the questionnaire was finished for that week. However, if the athlete reported anything other than the minimum value for any question, the questionnaire continued by asking them to define whether the problem they referred to was an illness or an injury. In the case of an injury, they were asked to register the area of the body in which it was located, and in the case of an illness, they were asked to select the major symptoms they had experienced. For all types of problems, the number of days of complete time loss, defined as the total inability to train or compete, was also registered. Athletes were also asked whether or not the problem had been reported previously, whether the problem was already being treated (and by whom) and whether

London 2012 Injury and Illness Surveillance Project

Please answer all questions regardless of whether or not you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

Question 1

Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past week?

☐ Full participation without health problems

☐ Full participation, but with injury/illness

☐ Reduced participation due to injury/illness

☐ Cannot participate due to injury/illness

Question 2

To what extent have you reduced you training volume due to injury, illness or other health problems during the past week?

☐ No reduction

☐ To a minor extent

☐ To a moderate extent

☐ To a major extent

☐ Cannot participate at all

Question 3

To what extent has injury, illness or other health problems affected your performance during the past week?

☐ No effect

☐ To a minor extent

☐ To a moderate extent

☐ To a major extent

☐ Cannot participate at all

Question 4

To what extent have you experienced symptoms/health complaints during the past week?

☐ No symptoms/health complaints

☐ To a mild extent

☐ To a moderate extent

☐ To a severe extent

Figure 2 The four key questions asked at the beginning of the weekly online Oslo Sports Trauma Research Center (OSTRC) Questionnaire on Health Problems. If the athlete answered the minimum value in each of the four questions, the questionnaire was finished for that week.

they had any further comments for their Olympic medical team. These three questions were included for use in the weekly reports rather than for epidemiological data collection purposes. Finally, athletes were asked whether the problem they had been referring to was the only health problem they had experienced during the preceding 7 days or whether they had experienced several problems. If they had only had one problem, the questionnaire was finished, whereas if they reported several problems, the questionnaire returned to the four key questions and repeated itself for each subsequent problem reported. The questionnaire logic is summarised in figure 3, and the complete

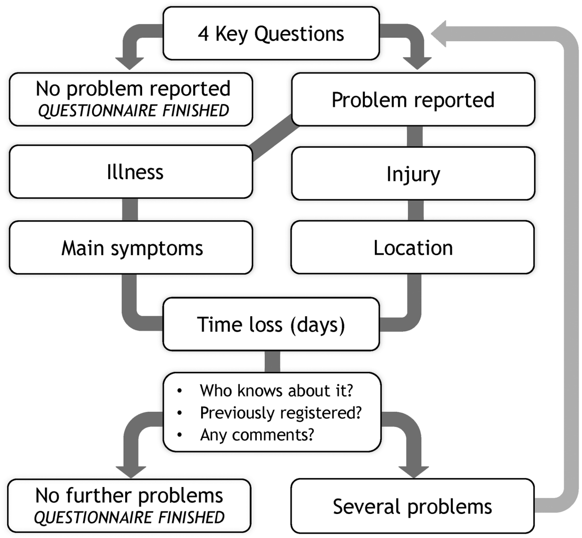

Figure 3 Diagram of questionnaire logic showing how the length of the questionnaire varied according to the number of health problems the athlete reported. Up to four health problems could be reported per week.

OSTRC Questionnaire is available as an online supplement appendix 1.

Classification and diagnosis of reported problems

Team medical personnel were asked to classify each problem reported as an illness, acute injury or overuse injury, based on their clinical interview. In accordance with the International Olympic Committee surveillance system,[3] health problems were classified as injuries if they were disorders of the musculoskeletal system or concussions. They were classified as illnesses if they involved other body systems, such as (but not limited to) the respiratory, digestive and neurological systems, as well as non-specific/generalised, psychological and social problems. Injuries were further subcategorised into overuse and acute injures. Acute injuries were defined as those whose onset could be linked to a specific injury event, whereas overuse injuries were those that could not be linked to a clearly identifiable event. The medical team was also asked to provide a specific diagnosis for each event. For illnesses, the International Classification of Primary Care, V.2 (ICPC-2) was used,[23] and for injuries the Orchard Sports Injury Classification System, V.10 (OSICS-10), was used.[24] The first tier of the OSICS-10 code was used to determine the location, and the second tier was used to determine the type. The first letter of the ICPC-2 code was used to determine the body system affected by illness.

At the conclusion of the project, the project coordinator manually went through each athlete's questionnaire responses and cross-checked all reported health problems with the classifications and diagnoses made by the medical team. All cases were checked twice for accuracy, and in 16 cases where information was missing or conflicting, medical personnel were contacted for clarification. In injury cases where the same diagnosis was interspersed with periods of apparent recovery, medical personnel were consulted in order to classify subsequent events as exacerbations of unresolved problems or recurrences of fully recovered problems (reinjuries), in accordance with the definitions outlined by Fuller *et al*.[25] Illnesses were treated in a similar fashion, with repeated episodes of chronic conditions treated as a single case for the purposes of analysis.

Prevalence calculations

Prevalence measures were calculated for all health problems, illnesses, injuries, overuse injuries and acute injuries for each week that the project was conducted. This was performed by dividing the number of athletes reporting any form of problem by the number of questionnaire respondents. The prevalence of substantial problems was also calculated for each of these measures, with substantial problems defined as those leading to moderate or severe reductions in training volume, or moderate or severe reductions in sports performance, or complete inability to participate in sport (ie, problems where athletes selected option 3, 4 or 5 in either Questions 2 or 3). All prevalence measures were also calculated for the four different subgroups of athletes: (1) team athletes (n=30), consisting of handball and beach volleyball players; (2) endurance athletes (n=53), consisting of athletes from cycling, kayak, rowing, swimming as well as the middle-distance and long-distance runners from athletics; (3) tactical/technical athletes (n=36), consisting of athletes participating in archery, boxing, sailing, shooting, taekwondo, weightlifting and wrestling, as well as the sprint and field athletes from athletics and (4) paralympic athletes (n=26). All prevalence measures were presented as averages, together with a 95% CI. Data from the first week the project was conducted were excluded from all calculations, as per our previous recommendations.[22]

Severity of health problems

Each week, a severity score was calculated for all reported health problems based on an athlete's responses to the four key questions.[22] The severity score was plotted in order to track the progression of each health problem, such as in the example shown in figure 4. The *cumulative severity score* was then calculated for each case by summing the severity score for each week that it was reported. The *average weekly severity score* was calculated by dividing the cumulative severity score by the number of weeks the problem was reported. The total amount of complete *time loss* was also calculated for each problem by summing the weekly reported time loss. For all the above calculations, recurrent problems were counted as the same event if they were deemed by the medical staff to be exacerbations of an unresolved injury or a chronic illness.

Relative burden of illness, overuse injury and acute injury

The cumulative severity scores for all health problems were summed, and the proportion of the total number made up by illness, overuse injury and acute injury was determined. This was performed in order to estimate the relative burden of these different types of health problems.

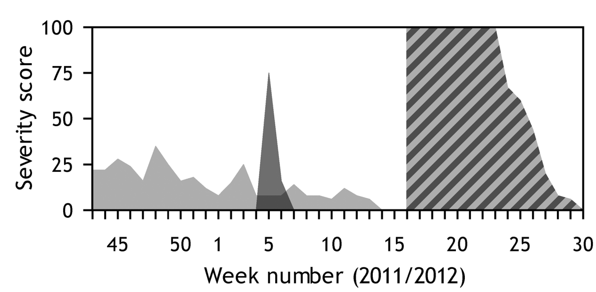

Figure 4 Example of the severity score being used to track the consequences of three 'typical' health problems. The light grey area represents a mild overuse injury (cumulative severity score: 352), the dark grey area represents a short duration illness (91) and the area with diagonal lines represents a severe acute injury (1005).

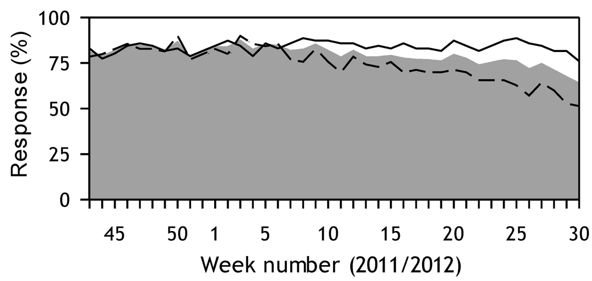

Figure 5 Response rate (%) to the weekly health questionnaires for the whole group (solid grey area), for the athletes selected for the Olympic and Paralympic Games (n=71, solid line) and for the athletes not selected for participation in the games (n=71, dashed line).

Statistical analyses

In order to analyse differences in the various prevalence measures between subgroups of athletes, Kruscal-Wallis non-parametric analysis of variance (ANOVA) tests were applied, using SPSS statistical software (SPSS V.18, IBM Corporation, New York, USA).

In order to analyse differences in the duration, cumulative severity and average weekly severity scores between different types of health problems, as well as between diagnosed and undiagnosed health problems, regression analyses were made. The repeated nature of measurements was taken into account by applying the robust option in the xtreg command in STATA statistical software (STATA V.12.0, StataCorp LP, Texas, USA). The significance level (α) was set at 0.05 for all tests.

As the original OSTRC questionnaire was developed for recording injury consequences,[22] it was necessary to reanalyse the psychometric properties of the four key questions when they were applied to illnesses. In order to do this, all questionnaires that did not report an injury (n=3384) were analysed using SPSS software to determine internal consistency (Cronbach's α). A factor analysis was also performed using a principle component analysis extraction method. Additionally, in order to assess the effects of sampling less frequently, the primary outcome measures were recalculated using only information from every second and fourth questionnaires.

RESULTS

Response rate to the weekly health questionnaires

The average weekly response rate to the health questionnaires was 80% (SD 5). The rate was 84% (SD 3) among athletes that were eventually selected for participation in London, while it was 75% (SD 10) among those that were not selected. Figure 5 shows the response rates for each of these groups during the course of the 40-week project. As illustrated, the response from non-selected athletes fell during the second half of the project.

Classification of problems reported

A total of 617 health problems were reported by 132 athletes over the course of the 40-week project, including 329 illnesses and 288 injuries. Of these, 582 cases (94%) were followed up by medical staff and classified with an ICPC-2 or OSICS-10 code. A majority of the 35 unclassified cases were brief and of mild severity, with their average duration being shorter than that of classified health problems (1 week (95% CI 1 to 2) vs 3 weeks (95% CI 3 to 3), p=0.03), and with their average cumulative severity being substantially lower (51 (95% CI 34 to 67) vs 118 (95% CI 99 to 137), p<0.01).

Prevalence of health problems

The average weekly prevalence of health problems reported was 36% (95% CI 34% to 38%), with 15% of athletes reporting substantial health problems each week (95% CI 14 to 16). As shown in table 1, overuse injury was the most prevalent type of health problem, and there was a variation in the prevalence of health problems between the various subgroups of athletes.

Over the course of the 40-week project, there was a general decline in the prevalence of illness, substantial illness, overuse injury and substantial overuse injury (figure 6), while the prevalence of acute injury increased slightly over the same period.

Injury data

A total of 288 injuries were reported by 115 athletes over the course of the study. Of these, 202 were classified as overuse injuries, 60 as acute injuries and 26 were unclassified. The average duration, average weekly severity score and average cumulative injury score for acute and overuse injuries are shown in table 2. As shown in the table, there were no significant

Table 1 Average weekly prevalence (percentage of athletes affected) of all health problems and substantial problems reported, as well as the prevalence of the subcategories illness, injury, overuse injury and acute injury in the whole group and each of the four subgroups of athletes

	Team n=30	Endurance n=53	Tactical/technical n=36	Paralympic n=26	Total cohort n=142
Health problems reported					
All	45 (42–48)**,***,****	30 (27–32)*,***	25 (21–28)*,**	29 (26–33)*	36 (34–38)
Illness	6 (5–8)**,***,****	16 (13–18)*,***	10 (9–12)*,**,****	16 (14–19)*,***	13 (12–14)
Injury	42 (39–45)**,***,****	17 (16–19)*	18 (14–22)*	19 (17–21)*	25 (24–27)
Overuse injury	31 (29–33)**,***,****	15 (13–17)*	16 (13–18)*	13 (12–14)*,**	20 (18–21)
Acute injury	10 (8–12)**,***,****	2 (1–2)*	3 (2–4)*	2 (1–3)*	4 (3–5)
Substantial problems					
All	16 (14–17)***	14 (13–16)***	11 (9–13)*,**,****	16 (14–19)***	15 (14–16)
Illness	2 (1–3)**,***,****	8 (6–10)*	6 (5–8)*	8 (6–10)*	6 (6–7)
Injury	14 (13–16)**,***,****	7 (6–7)*	5 (4–7)*,**,****	11 (9–12)*,**,***	9 (9–10)
Overuse injury	9 (8–11)**,***	6 (5–6)*	4 (3–5)*,**,****	10 (8–11)**,***	7 (6–8)
Acute injury	5 (4–6)**,***,****	1 (0–1)*	2 (1–2)*	1 (0–2)*	2 (2–3)

p<0.05 vs *team group, **endurance group, ***tactical/technical group, ****paralympic group.
All data are mean values with 95% CI in parenthesis. Substantial problem: causing moderate/severe reductions in training volume or sports performance, or complete inability to participate in training or competition.

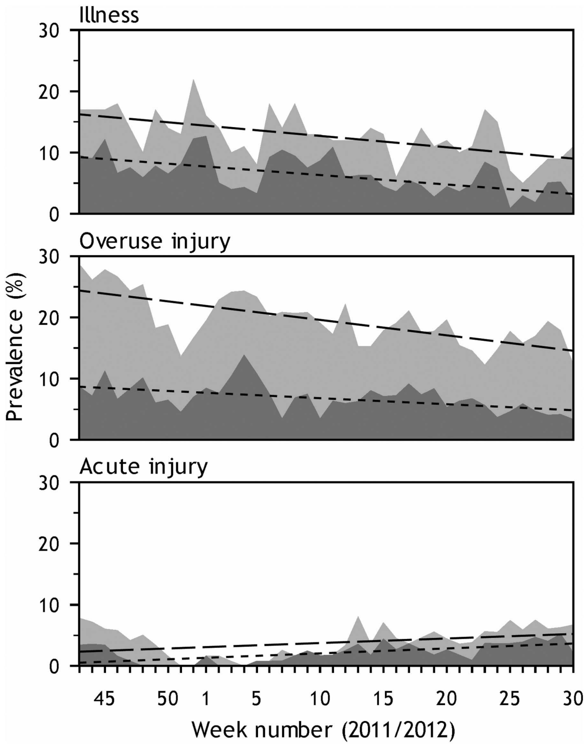

Figure 6 Prevalence of illness, overuse injury and acute injury over the 40-week study. Light grey area: all complaints (linear regression line=long dashes), dark grey area: substantial problems (linear regression line=short dashes).

differences between the average duration, average weekly severity score or average cumulative severity score between overuse and acute injuries, although overuse injuries tended to last longer (p=0.055).

Of the 288 injuries reported, 122 were substantial problems, including 86 overuse injuries and 27 acute injuries (9 were unclassified; average duration: 1.3 weeks, SD 0.5).

The location of acute and overuse injuries and their severity measured by time loss are shown in table 3. The most common overuse injury types were unspecified pain (29% of cases), muscle injury (25%), tendon injury (16%) and synovitis/impingement/bursitis (15%), while the most common types of acute injury were joint sprains (48%), muscle injury (15%) and bruising/haematoma (12%).

Illness data

A total of 329 illnesses were reported by 106 athletes over the course of the study, and 97% of cases were classified with an ICPC-2 code. Of the 329 illnesses reported, 198 represented substantial problems. The average weekly prevalence of illness and of substantial illness for the whole group and for each subgroup of athletes is shown in table 1. As shown in table 2, illnesses had a higher average weekly severity score than injuries. However, as their average duration was shorter, their average cumulative severity score was significantly lower. The most commonly affected systems were the respiratory system (68% of cases) and the digestive system (16%).

Table 2 Average duration, weekly severity score and cumulative severity score of illnesses, overuse injuries and acute injuries

	Illness n=329		Overuse injury n=202		Acute injury n=60	
Duration (weeks)	2	(2–2)	5	(4–6)*	3	(2–4)*
Average weekly severity score	45	(42–47)	32	(29–34)*	35	(30–40)
Cumulative severity score	78	(69–87)	169	(125–214)*	153	(66–240)*

*Significantly different to illness (p<0.03).
Data are mean values with the 95% CI in parenthesis.

Relative burden of illness, overuse injury and acute injury

When the cumulative severity score of all health problems was summed, overuse injuries represented 49% of the total number, illnesses represented 36% and acute injuries represented 13%. The remaining 2% consisted of unclassified injuries.

Psychometric questionnaire properties

The questionnaire had high internal consistency when all questionnaires were analysed, as well as for non-injury cases (Cronbach's α of 0.96 and 0.97, respectively). This was not improved by removing items in either case (table 4). The factor weighting was relatively even for all four questions in both cases.

Effects of different sampling frequencies on outcome measures

Sampling less frequently led to fewer cases being identified and a reduction in the average cumulative severity score and duration. However, the average prevalence and average weekly severity measures were not affected (table 5).

DISCUSSION

This paper describes a new approach to monitor athletes' health, and presents the first prospective data on the illness and injury patterns of Olympic and Paralympic athletes preparing for the games. The main findings were that, at any given time, 36% of athletes had some form of health problem, and 15% had a substantial illness or injury. The new method was able to show that overuse injuries represented the greatest burden on the group, owing to the large number of cases and the relatively long duration of consequences they had on the athletes' participation and performance. In contrast, illnesses were of significantly shorter duration and there were far fewer cases of acute injury.

The methods used in this study represent a modification of those we developed for recording overuse injuries in predefined anatomical areas,[22] such that they can be used to monitor all types of health complaints. Although the previous approach is more appropriate for the study of specific problems, such as shoulder problems, the current approach is better suited to general surveillance studies, particularly when the cohort is heterogeneous and a wide variety of complaints is expected. In both approaches, the methods differ considerably from those typically used in prospective surveillance studies as health problems are reported directly by athletes through regular online questionnaires, rather than via team medical staff. We have previously discussed the benefits and limitations of this approach in detail[21 22]; therefore, this discussion will focus primarily on the modifications made in the current study.

One of the principal modifications was to restructure OSTRC questionnaire: The four key questions were made more general (referring to *any health problem or complaint* rather than a specific anatomical area) and logical functions were used to register multiple problems. These changes were made to allow for the registration of all types of problems and to minimise the time burden of completing the questionnaire. However, in our experience, one of the limitations of trying to capture all problems is that fewer are identified than when specific questioning

Table 3 Location and degree of time loss for acute and overuse injuries

Location	Acute injuries: Slight (0 days)	Minimal (1–3 days)	Mild (4–7 days)	Moderate (8–28 days)	Severe (>28 days)	Total	Overuse injuries: Slight (0 days)	Minimal (1–3 days)	Mild (4–7 days)	Moderate (8–28 days)	Severe (>28 days)	Total
Head	1	2	1	–	–	4	–	–	–	–	–	–
Neck	1	–	–	–	–	1	5	2	2	1	–	10
Shoulder	–	1	1	1	–	3	22	3	1	–	4	30
Upper arm	–	–	–	–	–	–	1	–	–	1	–	2
Elbow	1	–	1	–	–	2	3	1	1	–	1	6
Forearm	–	–	–	–	–	–	3	–	1	–	–	4
Wrist and hand	10	6	–	1	–	17	3	2	1	–	–	6
Chest	–	–	–	–	–	–	1	1	–	–	–	2
Trunk and abdomen	–	–	–	–	–	–	–	1	1	–	–	2
Thoracic spine	1	–	–	–	–	1	6	2	–	1	–	9
Lumbar spine	–	–	–	–	1	1	14	6	4	3	–	27
Pelvis and buttock	–	–	–	–	–	–	3	1	2	–	–	6
Hip and groin	2	2	–	–	–	4	7	–	–	1	–	8
Thigh	1	5	1	2	–	9	10	3	1	–	–	14
Knee	2	–	1	–	1	4	19	9	3	3	2	36
Lower leg	–	1	–	1	–	2	3	2	3	1	–	9
Ankle	6	4	1	1	–	12	8	5	1	–	–	14
Foot	–	–	–	–	–	–	5	7	1	2	–	15
Disabled	–	–	–	–	–	–	–	2	–	–	–	2
Total	25	21	6	6	2	60	113	47	22	13	7	202

is used.[19] To combat this, we structured the questionnaire such that all athletes had to complete the four key questions regardless of whether or not they had any health problems to report. This prompted the athlete to consider the question *have you had any health problems* in several different ways.

A second modification was the use of team medical staff to classify and diagnose each health problem reported by athletes, allowing for the prospective collection of exact diagnoses, as well as a comprehensive subclassification of each case. As this method records all physical complaints, a considerable proportion of minor and transient cases are likely to be non-specific or difficult to diagnose. This was the case in the current study, where the most common type of overuse injury was 'unspecified pain,' representing 29% of all cases. Nevertheless, monitoring the prevalence of specific injury types, such as tendinopathy or stress fractures, becomes possible using this approach. In addition, the system of weekly feedback reports to team medical staff established to facilitate data collection (figure 1) also served as a practical tool to optimise medical coverage for the teams. This was important, as the athletes involved spent most of the preparatory period with their club, relying upon local/external medical support. The weekly reporting enhanced the Olympic medical team's awareness of health problems among their athletes, and in many cases this led to earlier and more comprehensive intervention. This is one potential explanation for the reduction in the prevalence of overuse and illness problems throughout the course of this study. However, it must be taken into consideration that by improving athletes' medical coverage, the system inherently affects its own data.

Table 4 Interitem and item–total correlations and effects of removing items on internal consistency

	Interitem correlation matrix: Question 1	Question 2	Question 3	Item–total correlation	Cronbach's α if item deleted
All questionnaires (n=4470)					
Question 1	–			0.92	0.94
Question 2	0.87	–		0.90	0.94
Question 3	0.89	0.88	–	0.92	0.94
Question 4	0.85	0.80	0.84	0.87	0.95
Non-injury cases (n=3384)					
Question 1	–			0.94	0.95
Question 2	0.91	–		0.91	0.96
Question 3	0.90	0.91	–	0.94	0.95
Question 4	0.87	0.82	0.88	0.88	0.96

A third modification is that, in addition to the average weekly severity score, an additional measure of severity, the cumulative severity score, was calculated for each health problem. This provides information on the relative impact each case has on the athlete, as it takes into account the degree of consequences and the duration of the problem. Summing cumulative severity scores also enables an estimation of the total burden of different types of problems, or within different groups of athletes. One important finding in the current study was that overuse injuries placed a much greater burden on the athletes than illnesses and acute injuries (49%, 36% and 13%, respectively, of the summed cumulative severity score), in contrast to what is typically found using standard surveillance methods.[7 9 15 26–29]

For acute injuries, we consider standard surveillance methods to be a satisfactory alternative to the new method, as it was arguably for this purpose that they were developed.[16 21] However, data collected by medical staff may not always be complete and accurate,[30 31] and systematic bias may be introduced when broad definitions are used.[32] As the methods used in this study do not rely on medical staff as the means of determining the occurrence of a case, a major source of systematic bias is eliminated. Therefore, the novel methodology may be a preferable alternative, particularly as recording all complaints is desirable in many instances.[33] It should be noted that data

Table 5 Variations in outcome measures with different sampling frequencies

	Sample Weekly	Sample every 2 weeks	Sample every 4 weeks
Number of completed questionnaires	4469	2244	1124
Number of health problems identified	617	428	294
Illnesses	329	216	132
Injuries	288	212	162
Number of substantial problems	320	220	131
Illnesses	198	129	71
Injuries	122	91	60
Average prevalence (all health problems)	36 (34–38)	36 (34–38)	37 (34–40)
Average prevalence (substantial)	15 (14–16)	16 (14–17)	16 (14–17)
Average weekly severity score	40 (38–42)	40 (38–42)	38 (35–41)
Average cumulative severity score	114 (96–132)	83 (71–95)	60 (51–69)
Average duration of problems (weeks)	3 (3–3)	2 (2–2)	2 (1–2)

collected using the new method can also be presented according to consensus guidelines,[16] as demonstrated in table 3.

Although illnesses are increasingly being included in surveillance studies,[6–8 10 11 26 34] there is a wide variation in the way in which they are recorded and reported. Similar to injuries, issues are likely to arise when recording illnesses using standard prospective methods, particularly as athletes with mild or chronic conditions are likely to continue to participate in sport. The methods used in this study may therefore be a good option when these problems are of interest. Although OSTRC Questionnaire was first developed for the study of injuries, our analyses of its psychometric properties suggest that it may also be appropriate to monitor illness consequences.

It must be acknowledged that the success of this method of data collection is entirely dependent on a good response from athletes, as well as a thorough follow-up from team medical staff to record diagnoses. In the current study, the average response rate of 80% was high, as was the percentage of cases successfully diagnosed (94%). However, this was a study of highly motivated elite athletes in a well-organised Olympic team structure, and it is not yet known how these methods will function in other settings.

Finally, as in our previous paper, we performed data simulations of the effects of administering questionnaires every second and fourth week, rather than weekly. The results indicate that, in future epidemiological studies using this method, it is possible to sample less frequently as the primary outcome measures, average prevalence and severity are unchanged. However, the data simulations highlight the fact that cumulative severity scores are not comparable between studies unless the studies are of the same duration and use the same sampling frequency. Also, as fewer problems are identified and the frequency of reporting to the medical team is reduced, administering questionnaires less frequently would comprise this method's value as a practical health monitoring tool.

CONCLUSION

This paper presents a new approach to recording all types of health problems in sport, showing that the method is sensitive and valid in documenting the pattern of acute injuries, overuse injuries and illnesses in a large, heterogeneous group of athletes during a 40-week preparatory period before the Olympic and Paralympic Games. Overuse injuries represented a much greater burden (49%) on the athletes than illnesses (36%) and acute injuries (13%), in contrast to what is typically found using standard surveillance methods.

What are the new findings?

- A new approach to monitor athletes' health using regular online questionnaires enables valid and reliable registration of all types of problems, including illness, overuse injury and acute injury.
- At any given time, more than one in three athletes preparing for the Olympic or Paralympic Games had health problems.
- Overuse injuries represented the greatest burden on athletes' health, in comparison to acute injuries and illnesses.

How might it impact on clinical practice in the near future?

This paper may lead to a change in the methods used in surveillance studies of athletes, particularly when overuse injuries and illnesses are of interest.

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Contributors All authors were involved in planning the project, data collection and preparing the manuscript. BMC was responsible for co-ordination of the data collection and for data analysis. BMC is responsible for the overall content as the guarantor.

Competing interests None.

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Data sharing statement Unpublished data are available upon request.

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Appendix I

Informed consent forms and approval letters from the Regional Committee for Medical Research Ethics (REK) and the Norwegian Data Inspectorate (NSD)

FORESPØRSEL OM DELTAKELSE I PROSJEKTET:

"Belastningskader i sykling/langrenn/håndball/volleyball/innebandy"

Bakgrunn for undersøkelsen

Belastningsskader i idrett har i det siste vært et svært aktuelt tema, både i media og i forskningssammenheng. Kunnskap fra vitenskaplige studier og vår kliniske erfaring, viser at i enkelte idretter trener og konkurrerer mer en 50 % av utøvere med belastningsskader. Disse skadene kan ha store konsekvenser for prestasjoner og helse.

Problemet så langt er imidlertid at metodene for å kunne måle forekomsten og alvorlighetsgraden av belastningsskader i idrett ikke er gode nok. Denne informasjonen er en viktig brikke i arbeidet med å forebygge belastningsskader i idretten. Vi ønsker nå å utvikle en ny metodikk for å registrere skader, for å kartlegge skadeforekomsten i sykling/langrenn/håndball/volleyball/innebandy.

Senter for idrettsskadeforskning er en forskningsgruppe bestående av fysioterapeuter, leger og biomekanikere med kunnskap innen idrettsmedisin. Vår hovedmålsetting er å forebygge skader i norsk idrett. Senteret er finansiert av Helse Sør-Øst, Kulturdepartementet, Norges idrettsforbund og olympiske komité, samt Norsk Tipping AS, og holder til på Norges idrettshøgskole (NIH) i Oslo. Vi har også hatt flere andre prosjekter tidligere der vi har samarbeidet med Norges fotballforbund, Norges håndballforbund og Norges volleyballforbund.

Gjennomføring av prosjektet

Vi ønsker at du som utøver deltar i denne studien, men understreker at deltakelsen er frivillig. Undersøkelsen innebærer å fylle ut et kort spørreskjema om belastningsskader, en gang i uken i tolv uker. Spørreskjemaet blir tilsendt på e-post ukentlig. Det tar bare om lag 5 minutter å fylle ut. . I studieperioden skal treneren din også notere hvor mye ditt lag trener og konkurrerer, samt om du ikke kan delta på trening på grunn av skader. Dersom du blir skadet under trening eller kamp/konkurranse, vil du da bli ringt opp av en fysioterapeut for et kort intervju om skaden. I tillegg vil vi kanskje måtte ringe deg opp for et kort intervju når registreringsperioden er over etter 3 måneder.

Behandling av data

Vi vil registrere alle skader som oppstår i ditt, og flere andre lag, over en 3-måneders periode. Derfor blir det nødvendig å lagre ditt navn og lag sammen med dine svar på spørreskjemaet mens studien pågår. I denne perioden vil dataene bli behandlet konfidensielt, og kun i forskningsøyemed. Alle som fyller ut spørreskjemaene og forskere som benytter dataene er underlagt taushetsplikt. Etter at datainnsamlingen er ferdig, vil alle dine data bli anonymisert. Da skal det ikke bli mulig å kunne identifisere deg i våre arkiver, og det skal ikke bli mulig å kunne identifisere deg eller ditt lag i eventuelle rapporter om denne studien.

Hva får du ut av det?

Når undersøkelsen er ferdig vil vi samle lagene og legge frem resultatene i forbindelse med en sosial samling. Vi ønsker å gi informasjon om hvordan skadene kan forebygges. I tillegg vil vi trekke tre gavekort til sportsutstyr a kr 2000 til de av utøverne som har svart innen fristene.

Angrer du?

Du kan selvfølgelig trekke deg fra studien når som helst uten å måtte oppgi noen grunn. Alle data som angår deg vil i så fall bli anonymisert.

Spørsmål?

Ring gjerne til Grethe Myklebust, tlf.: 23 26 23 70 hvis du har spørsmål om prosjektet, eller send e-post til grethe.myklebust@nih.no.

NORGES IDRETTSHØGSKOLE

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

"En ny metodikk for registrering av belastningskader i sykling/langrenn/håndball/volleyball/innebandy"

SAMTYKKEERKLÆRING

Jeg har mottatt skriftlig og muntlig informasjon om studien "*en ny metodikk for registrering av belastningskader i sykling/langrenn/håndball/volleyball/innebandy*." Jeg er klar over at jeg kan trekke meg fra undersøkelsen på et hvilket som helst tidspunkt.

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NORGES IDRETTSHØGSKOLE

SENTER FOR
Idrettsskadeforskning
KLOKE AV SKADE

FORESPØRSEL OM DELTAKELSE I PROSJEKTET

Risikofaktorer for skulderskader hos mannlige elitehåndballspillere: En prospektiv kohortstudie

Bakgrunn for undersøkelsen

Belastningsskader i skulderleddet hos håndballspillere har i det siste vært et svært aktuelt tema, både i media og i forskningssammenheng. Dette skyldes først og fremst den store hyppigheten av denne type skade blant håndballspillere, som vi tror kan påvirke mer en 50 % i den norske eliteserien. Problemet så langt er imidlertid at vi vet for lite om risikofaktorene og skademekanismene for skulderskader hos handballspillere. Denne informasjonen er viktig når vi forsøker å forebygge skader, både for å kunne vite hvem som vil ha størst glede av forebyggende trening og for å kunne utvikle mest mulig effektive treningsmetoder.

Senter for idrettsskadeforskning er en forskningsgruppe bestående av fysioterapeuter, kirurger og biomekanikere med kunnskap innen idrettsmedisin. Vår hovedmålsetting er å forebygge skader i norsk idrett, med spesiell satsning på fotball, håndball, ski og snowboard. Denne studien er en viktig brikke i arbeidet med å finne ut hvorfor noen får en skuldeskade. Vi ønsker nå å undersøke ulike mulige risikofaktorer for skader, for deretter å kartlegge hvem som får skulderproblemer den påfølgende sesongen.

Gjennomføring av undersøkelsen

Vi ønsker at du som elitespiller deltar i denne studien, og deltakelsen er frivillig. Testingen vil finne sted på en vanlig trening i høsten 2011. I løpet av en trening vil vi gjennomføre ulike styrke- og bevegelighetstester i skulderleddet, samt gjennomføre en bevegelsesanalyse av hvordan du kontrollere skuldrene dine når du løfter armene dine og hvordan du kontrollere korsryggen når du gjører knebøy på ett bein. Under disse analyser vil det være et videokamera som filmer dine bevegelser.

Testingen vil ta ca. 20 minutter. I tillegg til disse testene vil du få utdelt et skjema, der vi spør om treningserfaring og spilleposisjon, tidligere skader, og skulderfunksjon. Spørreskjemaet besvares i løpet av testdagen, og det vil ta ca. 10 min.

Behandling av testresultatene

Vi vil den neste sesongen følge opp alle lag og spillere som har deltatt på testing hos oss, for å registrere alle skulderskader som oppstår. Dataene vil bli behandlet konfidensielt, og kun i forskningsøyemed. Alle som utfører testingen og forskere som benytter dataene er underlagt taushetsplikt.

Vi vil underveis i testingen ta videoopptak av dere som vi senere kan ønske å bruke i undervisnings- og formidlingssammenheng. Opptakene inkluderer situasjoner der dere kun har på shorts. Dersom dere ikke vil at deres opptak skal være aktuelle for slik bruk krysser dere av for det i samtykkeerklæringen.

Hva får du ut av det?

Du vil få kopi av dine resultater fra styrketestene som gjennomføres i løpet av testingen

Angrer du?

Du kan selvfølgelig trekke deg fra forsøket når som helst uten å måtte oppgi noen grunn. Alle data som angår deg vil uansett bli anonymisert.

Spørsmål?

Ring gjerne til Grethe Myklebust, tlf.: 23 26 23 70 hvis du har spørsmål om prosjektet, eller send e-post til grethe.myklebust@nih.no.

NORGES IDRETTSHØGSKOLE

SENTER FOR
Idrettsskadeforskning
KLOKE AV SKADE

SAMTYKKEERKLÆRING

Risikofaktorer for skulderskader hos mannlige elitehåndballspillere: En prospektiv kohortstudie

Jeg har mottatt skriftlig og muntlig informasjon om studien *Risikofaktorer for skulderskader hos mannlige elitehåndballspillere - En prospektiv kohortstudie*. Jeg er klar over at jeg kan trekke meg fra undersøkelsen på et hvilket som helst tidspunkt.

☐ Jeg ønsker ikke at video av meg skal brukes i undervisningssammenheng

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Sted Dato

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Olympiatoppens sykdom og skaderegistrering

Vi ønsker å sikre at du som aktuell OL/paralympics-kandidat til London får den medisinske hjelpen du trenger, så raskt så mulig. Samtidig, sammen med Senter for Idrettsskadeforskning ved Norges Idrettshøgskole, ønsker vi å bruke informasjonen som samles inn til å hjelpe med å utvikle effektive forebyggende tiltak for fremtidige OL/Paralympics utøvere.

Vi ber at du hver uke frem til OL/paralympics i London fyller ut et elektronisk spørreskjema med informasjon om skader, sykdommer og helseplager du vært berørt av siste uke. Det medisinske teamet til ditt landslag vil få informasjonen slik at de på best mulig måte og uten opphold kan følge opp deg. Det er viktig å poengtere at denne registreringen ikke erstatter kontakten du ellers har med lagets lege og fysioterapeut. Du må fortsette å bruke dem på vanlig måte, men med denne registreringen håper vi å kunne forsikre oss om at alle får den beste mulige oppfølging i en viktig kvalifisering og forberedelsesperiode.

For å kunne gjennomføre dette trenger vi ditt samtykke. Deltakelse er frivillig og du kan trekke deg når du måtte ønske det uten noen form for begrunnelse. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og lagets støtteapparat som kan finne tilbake til deg. Vi ber også om å kunne benytte dataene som samles inn til forskningsformål. Alle data vil bli anonymisert og resultatene vil bli presentert på gruppenivå og på en slik måte at det ikke vil være mulig å identifisere deg når disse publiseres. Når studien er avsluttet og alle data er analysert, ikke senere enn 15. august 2014 vil informasjonen bli slettet.

Med vennlig hilsen,

Dr Ola Rønsen, *Sjefslege London OL*
Dr Tonje Flørenes, *Lege Olympiatoppen*

Dr Roald Bahr, *Sjefslege Olympiatoppen*
Ben Clarsen, *Prosjekt koordinator*

Samtykke (sett kryss)
Jeg har lest og forstått informasjonen over og gir mitt samtykke til å:

☐ samle inn informasjon om mine sykdommer og skader frem til OL/Paralympics i 2012
og
☐ vitenskapelig forskning på samlet data

Sted, dato	Navn	Signatur

Ved spørsmål om prosjektet kontakt Dr Ola Rønsen, mob:41900363, email: ola.ronsen@olympiatoppen.no

UNIVERSITETET I OSLO

DET MEDISINSKE FAKULTET

1 amanuensis Grethe Myklebust
Norges Idrettshøgskole
Postboks 4014, Ullevål stadion
0806 Oslo

Regional komité for medisinsk og helsefaglig forskningsetikk Sør-Øst C (REK Sør-Øst C)
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 22 84 46 67

E-post: post@helseforskning.etikkom.no
Nettadresse: http://helseforskning.etikkom.no

Dato: 18.10.2010
Deres ref.:
Vår ref.: 2010/2294 (oppgis ved henvendelse)

Ny metodikk for registrering av belastningsskader i idrett

Vi viser til søknad mottatt til frist 02.09.2010 om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden er blitt vurdert av Regional komité for medisinsk og helsefaglig forskningsetikk i henhold til lov av 20. juni 2008 nr. 44, om medisinsk og helsefaglig forskning (helseforskningsloven) kapittel 3, med tilhørende forskrift om organisering av medisinsk og helsefaglig forskning av 1. juli 2009 nr 0955.

Dagens metoder for skaderegistrering baserer seg på at skadetype og alvorlighetsgrad registreres ved hjelp av et spørreskjema. Varighet av fravær fra idrett brukes som mål på alvorlighetsgrad. I de senere årene har fokuset på belastningsskader i idretten økt. Disse skadene fører ofte ikke til fravær fra idrett, og vil dermed ved vanlig skaderegistrering ikke bli registrert, til tross for at de kan være forbundet med betydelig smerter og nedsatt funksjon. Hensikten med dette prosjektet er å sammenlikne standard metodikk med nyutviklede spørreskjema og metodikk for belastningsskader. Skjema er utviklet for kne, rygg og skulderproblemer. Man vil undersøke i hvilken grad de to metodene fanger opp akutte- og belastningsskader, og i hvilken grad informasjonen overlapper hverandre eller gir utfyllende informasjon.

Prosjektleder: Grethe Myklebust
Forskningsansvarlig: Norges Idrettshøyskole

Komiteen anser formålet med denne studien å kartlegge og registrere skader og skadeforekomst innen idrettene langrenn/håndball/volleyball og innebandy. Det vises i den forbindelse til den vitenskapelige protokollens side 3: *Hensikten med prosjektet er å utvikle metodikk for registrering av belastningsskader til bruk i prospektive kohortstudier og intervensjonsstudier.* Metoden vil gjøre en i stand til å identifisere felt som vil kunne føre til nye forskningsstudier, med mer presise og spissede hypoteser.

Komiteen vurderer studien til å falle utenfor bestemmelsene i helseforskningsloven, jf. helseforskningslovens § 2. Komiteen utelukker imidlertid ikke at *funnene* i dette prosjektet kan danne grunnlaget for senere studier som må søkes REK.

Vedtak:
Prosjektet er ikke fremleggelsespliktig, jf. helseforskningslovens § 10, jf. helseforskningslovens § 4 annet ledd.

Vi gjør oppmerksom på at det for behandling av personopplysninger i prosjektet likevel kan være nødvendig med tillatelse fra personvernombudet for forskning eller Datatilsynet. De bør derfor ta kontakt med hhv. Datatilsynet eller Personvernombudet for å avklare disse spørsmålene.

REK antar for øvrig at prosjektet kommer inn under de interne regler for behandling av pasient-/helseopplysninger som gjelder ved forskningsansvarlig virksomhet.

Komiteens avgjørelse var enstemmig.

Komiteens vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag, jf. Forvaltningslovens § 28 flg. Eventuell klage sendes til REK Sør-Øst. Klagefristen er tre uker fra mottak av dette brevet.

Med vennlig hilsen

Arvid Heiberg (sign.)
professor dr. med.
leder

Tor Even Svanes
Tor Even Svanes
seniorrådgiver

Kopi: Kopi: Norges Idrettshøgskole, avd. for forskningsforvaltning og dokumentasjon, Postboks 4014, Ullevål Stadion, 0806 Oslo

Vi ber om at alle henvendelser sendes inn via vår saksportal: http://helseforskning.etikkom.no eller på e-post til: post@helseforskning.etikkom.no. Vennligst oppgi vårt saksnummer/referansenummer i korrespondansen.

25-10-10. Snakket med T.E. Svanes og han sa at denne studien er utenfor helseforsk-loven. Hvis behov for brev fra REK ved publ. utenlands, kan det fås ved kontakt med REK igjen.
„Idrettsskadeprosj. er i gråsonen i forh. til loven derfor ofte ønske å vurdere."

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst A	Jørgen Hardang	22845516	24.06.2011	2011/1104
			Deres dato:	Deres referanse:

Benjamin Clarsen
Norges Idrettshøgskole
Oslo

2011/1104a Risikofaktorer for skulderskader hos mannlige elite handball spillere

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk i møtet 9. juni 2011. Søknaden er vurdert i henhold til lov av 20. juni 2008 nr. 44, om medisinsk og helsefaglig forskning (helseforskningsloven) kapittel 3, med tilhørende forskrift om organisering av medisinsk og helsefaglig forskning av 1. juli 2009 nr 0955.

Prosjektleder: Benjamin Clarsen

Forskningsansvarlig: Norges Idrettshøgskole

Prosjektet har som mål å frembringe kunnskap om risikofaktorer og skademekanismer for skulderskader hos håndballspillere. Etter avgitt samtykke skal bevegelighet og styrke i skulderregionen undersøkes med metoder som er standardisert og som har vært brukt i flere vitenskaplige undersøkelser av andre idrettsutøvere, blant annet baseball og tennis spillere. Videre skal deltagerne svare på spørsmål om mulige skulderproblemer.

Prosjektet fremstår som et idrettsmedisinsk prosjekt hvor det skal anvendes anerkjente, svært lite belastende undersøkelser på frivillige aktive idrettsutøvere. Målet er ikke ny kunnskap om diagnose og behandling, men om skadetilstanden blant elitespillere. Undersøkelsen innebærer ingen spesiell risiko eller belastning for idrettsutøverne. En slik kartlegging kan gjøres om en del av oppfølgingen av spillerne med tanke på forebyggende arbeid.

Vedtak

Etter søknaden fremstår prosjektet som idrettsfaglig prosjekt som en del av oppfølgingen av elitespillere. Det faller derfor utenfor helseforskningslovens virkeområde, jf. § 2. Prosjektet kan gjennomføres uten godkjenning av REK.

Komiteens vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag, jfr. helseforskningsloven § 10, 3 ledd og forvaltningsloven § 28. En eventuell klage sendes til REK Sørøst A. Klagefristen er tre uker fra mottak av dette brevet, jfr. forvaltningsloven § 29.

Med vennlig hilsen

Gunnar Nicolaysen
professor dr. med.
leder

Jørgen Hardang
Jørgen Hardang
seniorrådgiver

Kopi: Norges Idrettshøgskole ved øverste administrative ledelse: postmottak@nih.no

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Tor Even Svanes	22845521	13.10.2011	2011/1686
			Deres dato:	**Deres referanse:**
			23.08.2011	

Ola Rønsen
Olympiatoppen
Postboks 4004
0806 Oslo

2011/1686 Monitorering av sykdom og skader hos OL og paralympics utøvere

Vi viser til søknad mottatt til møtet 26.09.2011 om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden er blitt vurdert av Regional komité for medisinsk og helsefaglig forskningsetikk i henhold til lov av 20. juni 2008 nr. 44, om medisinsk og helsefaglig forskning (helseforskningsloven) kapittel 3, med tilhørende forskrift om organisering av medisinsk og helsefaglig forskning av 1. juli 2009 nr 0955.

Prosjektleder: Ola Rønsen
Forskningsansvarlig: Olympiatoppen

De olympiske leker (OL) og paralympiske leker arrangeres hver fjerde sommer og hver fjerde vinter og er store verdensomspennende evenement som skaper mye entusiasme og oppmerksomhet. Utøvere som deltar i OL/paralympics er våre beste utøvere og er avhengige av å være skadefrie og ha minimalt med andre helseproblemer for å kunne trene optimalt og yte maksimalt for sin sport og nasjon i konkurranser og mesterskap. Vi vet samtidig at idrett på høyt nivå medfører økt risiko for idrettsskader, både akutte og i form av slitasje. For sykdom og helseplager har vi ikke like mye dokumentasjon. Vi ønsker med dette prosjektet å sikre at de som er aktuelle OL/paralympics-kandidater til London 2012 får den medisinske hjelpen de trenger og så rask som mulig. I tillegg håper vi at informasjonen som samles inn forhåpentligvis kan hjelpe med å utvikle effektive forebyggende tiltak for fremtidige OL/paralympics utøvere.

Etter søknaden fremstår ikke prosjektet som et medisinsk eller helsefaglig forskningsprosjekt, og faller derfor utenfor komiteens mandat, jf. helseforskningslovens § 2.

Vedtak:
Prosjektet er ikke fremleggelsespliktig, jf. helseforskningslovens § 10, jf. helseforskningslovens §4 annet ledd.

REK antar for øvrig at prosjektet kommer inn under de interne regler for behandling av opplysninger som gjelder ved forskningsansvarlig virksomhet.

Komiteens avgjørelse var enstemmig.

Komiteens vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag, jf. Forvaltningslovens § 28 flg. Eventuell klage sendes til REK Sør-Øst. Klagefristen er tre uker fra mottak av dette brevet.

Med vennlig hilsen

Berit Grøholt
professor dr. med.
nestleder

Tor Even Svanes
seniorrådgiver

Kopi: Olympiatoppen: ola.ronsen@olympiatoppen.no

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47-55 58 21 17
Fax: +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Benjamin Clarsen
Olympiatoppen
Postboks 4004
0806 OSLO

Vår dato: 30.01.2012 Vår ref: 28470 / 3 / PB Deres dato: Deres ref:

TILRÅDING AV BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 18.10.2011. All nødvendig informasjon om prosjektet forelå i sin helhet 27.01.2012. Meldingen gjelder prosjektet:

28470	*Monitorering av sykdom og skader hos OL og paralympics utøvere*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Benjamin Clarsen*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/-helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/forsk_stud/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://www.nsd.uib.no/personvern/prosjektoversikt.jsp.

Personvernombudet vil ved prosjektets avslutning, 15.08.2014, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Vigdis Namtvedt Kvalheim Pernilla Bollman

Kontaktperson: Pernilla Bollman tlf: 55 58 24 10
Vedlegg: Prosjektvurdering

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 28470

Prosjektet er et samarbeidsprosjekt mellom Norges idrettshøgskole og Olympiatoppen.

Formålet med prosjektet er å sikre at de som er aktuelle OL/paralympics-kandidater til London 2012 får den medisinske hjelpen de trenger så rask som mulig. I tillegg ønsker man at informasjonen som samles inn kan bidra til å utvikle effektive forebyggende tiltak for fremtidige OL/paralympics utøvere.

Utøverne (OL/paralympics-kandidater til London 2012) vil bli bedt om å fylle ut ukentlige spørreskjemaer med informasjon om de har hatt skader, sykdom eller helseplager siste uke, om og hvordan dette har innvirket på trening/konkurranse og hvilken type skade/sykdom dette har vært. Klassifisering av skader følger konsensus-rapporter bl.a fra den Internasjonale Olympiske Komitee. Ettersom hovedformålet med studien er å forsikre at utøverne får rask og riktig behandling vil det medisinske støtteapparatet til de aktuelle idrettene motta en rapport hver uke over sine utøvere med informasjon om de har hatt skader/plager slik at de skal kunne optimalisere behandlingsforløpet. Spørreskjemaene skal besvares hver uke frem til oppstart av OL i London sommeren 2012. Spørreskjemaer administreres av Questback. Personvernombudet for forskning anbefaler at det opprettes en databehandleravtale med Questback, jf. personopplysningsloven § 15.

Prosjektet vil omfatte behandling av sensitive personopplysninger om helseforhold, jf. personopplysningsloven § 2 pkt. 8 c.

Direkte personidentifiserende opplysninger i form av navn og kontaktopplysninger oppbevares atskilt fra datamaterialet, men kan kobles til dette ved hjelp av en koblingsnøkkel. Senest ved prosjektslutt 15.08.2014 vil datamaterialet anonymiseres ved at koblingsnøkkel slettes samt at eventuelle indirekte identifiserende opplysninger fjernes/grovkategoriseres. Spørreskjemaer som eventuelt ligger igjen på Questback sin server slettes.

Personvernombudet for forskning mottok 27.01.2012 reviderte informasjonsskriv som skal brukes ved rekruttering av respondenter samt i tilknytning til ukentlig spørreskjema. Ombudet finner skrivene tilfredsstillende og finner at behandlingen av personopplysninger kan foretas med hjemmel i personopplysningsloven §§ 8 første ledd (samtykke), 9 a.

Appendix II

The Oslo Sports Trauma Research Center Overuse Injury Questionnaire

Oslo Sports Trauma
RESEARCH CENTER

OSTRC Overuse Injury Questionnaire

Part 1: Knee Problems

Please answer all questions regardless of whether or not you have problems with your knees. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

The term "knee problems" refers to pain, ache, stiffness, swelling, instability/giving way, locking or other complaints related to one or both knees.

Question 1

Have you had any difficulties participating in normal training and competition due to knee problems during the past week?

- ☐ Full participation without knee problems
- ☐ Full participation, but with knee problems
- ☐ Reduced participation due to knee problems
- ☐ Cannot participate due to knee problems

Question 2

To what extent have you reduced you training volume due to knee problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

To what extent have knee problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

To what extent have you experienced knee pain related to your sport during the past week?

- ☐ No pain
- ☐ Mild pain
- ☐ Moderate pain
- ☐ Severe pain

Oslo Sports Trauma RESEARCH CENTER

OSTRC Overuse Injury Questionnaire

Part 2: Lower Back Problems

Please answer all questions regardless of whether or not you have problems in your lower back. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

The term "lower back problems" refers to pain, aching, stiffness or other problems in your lower back.

Question 1

Have you had any difficulties participating in normal training and competition due to lower back problems during the past week?

- ☐ Full participation without lower back problems
- ☐ Full participation, but with lower back problems
- ☐ Reduced participation due to lower back problems
- ☐ Cannot participate due to lower back problems

Question 2

To what extent have you reduced you training volume due to lower back problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

To what extent have lower back problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

To what extent have you experienced lower back pain related to your sport during the past week?

- ☐ No pain
- ☐ Mild pain
- ☐ Moderate pain
- ☐ Severe pain

Oslo Sports Trauma
RESEARCH CENTER

OSTRC Overuse Injury Questionnaire

Part 3: Shoulder Problems

Please answer all questions regardless of whether or not you have problems in your shoulders. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

The term "shoulder problems" refers to pain, aching, stiffness, looseness or other complaints in one or both of your shoulders.

Question 1

Have you had any difficulties participating in normal training and competition due to shoulder problems during the past week?

- ☐ Full participation without shoulder problems
- ☐ Full participation, but with shoulder problems
- ☐ Reduced participation due to shoulder problems
- ☐ Cannot participate due to shoulder problems

Question 2

To what extent have you reduced you training volume due to shoulder problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

To what extent have shoulder problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

To what extent have you experienced shoulder pain related to your sport during the past week?

- ☐ No pain
- ☐ Mild pain
- ☐ Moderate pain
- ☐ Severe pain

OSTRC Overuse Injury Questionnaire

Part 4: Anterior Thigh Problems

Please answer all questions regardless of whether or not you have problems in your thighs. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

The term "anterior thigh problems" refers to pain, aching, stiffness or other complaints in the front of one or both of your thighs (Quadricep muscles).

Question 1

Have you had any difficulties participating in normal training and competition due to anterior thigh problems during the past week?

- ☐ Full participation without anterior thigh problems
- ☐ Full participation, but with anterior thigh problems
- ☐ Reduced participation due to anterior thigh problems
- ☐ Cannot participate due to anterior thigh problems

Question 2

To what extent have you reduced you training volume due to anterior thigh problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

To what extent have anterior thigh problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

To what extent have you experienced anterior thigh pain related to your sport during the past week?

- ☐ No pain
- ☐ Mild pain
- ☐ Moderate pain
- ☐ Severe pain

Appendix III

Modified Fahlström Questionnaire

SPØRRESKJEMA ANGÅENDE SKULDERSMERTER I HÅNDBALL

Dato

Navn	
Subjektnr	
Klubb	

Fødselsdato ________ Høyde ________________ Vekt ______________

Spillerposisjon

Hø kant ☐ Midt back ☐ Ve. Kant ☐ Målvakt ☐

Hø back ☐ Ve. Back ☐ Strek ☐

Gjennomsnittlig antall timer håndball/uke (trening og kamp) ______ timer

Gjennomsnittlig antall timer øvrig trening for skuldrene/uke (eks styrketrening) _____ timer

Hvor mange år har du spilt håndball? ________ år

Hvor mange år har du spilt i eliteserien? ________ år

1. Har du hatt vondt i skuldrene i forbindelse med håndballspill - nå eller tidligere?

Ja ☐ **Nei** ☐

Hvis svaret er nei, er du ferdig med denne siden. Hvis svaret er ja - fortsett nedenfor

2. Har du vondt i skuldrene akkurat nå?

Ja ☐ **Nei** ☐

Hvis nei, fortsett på punkt 3.

Hvis ja - hvilken skulder? Høyre ☐ Venstre ☐ Begge ☐

Hvor lenge har du hatt vondt? .... (uker)

Hvordan begynte smertene? Plutselig ☐ over tid ☐

Når har du vondt?

☐ Når du bruker/belaster skulderen?

☐ Etter bruk av skulderen

☐ Av og til uavhengig av bruk/belastning av skulderen

☐ Hele tiden

Hvor intens er smerten når du har vondt? Marker med ett kryss på linjen

Ingen smerte |————————————————————| Værst tenkelig smerte

Har dine skuldersmerter gjort at du må endre på treningen din Ja ☐ Nei ☐

Har dine skuldersmerter gjort at du ikke kan spille kamp? Ja ☐ Nei ☐

Påvirker skuldersmerter dine daglige aktiviteter for øvrig (f.eks løfte, gre håret etc)? Ja ☐ Nei ☐

Gjør skuldersmertene at du har problemer med å sove? Ja ☐ Nei ☐

Føler du deg støl/stiv i skulderen? Ja ☐ Nei ☐

Har du søkt medisinsk hjelp for dine skuldersmerter? Ja ☐ Nei ☐

Hvis ja, hvem har du søkt hjelp hos? Lege ☐ Fysioterapeut ☐ Annet ☐ ....

Har du fått noen diagnose? Ja ☐ Nei ☐
Hvis ja, hvilken? ....

Har du fått noen behandling? Ja ☐ Nei ☐
Hvis ja, hvilken? ....

3. Hvis du ikke har vondt i skuldrene akkurat nå - har du hatt vondt i skuldrene tidligere?

Ja ☐ **Nei** ☐

Hvis ja - hvilken skulder? Høyre ☐ Venstre ☐ Begge ☐
Hvor lenge siden er det du hadde vondt? .... Uker
Hvor lenge har du hatt vondt? .... (uker)

Hvordan begynte smertene? Plutselig ☐ over tid ☐
Når hadde du vondt?

☐ Ved bruk/belastning av skulderen

☐ Etter bruk av skulderen

☐ av og til uavhengig av bruk/belastning av skulderen

☐ Hele tiden

Hvor intensiv er smerten når du har vondt? Marker med ett kryss på linjen

Ingen smerte |————————————————| Værst tenkelig smerte

Gjorde dine skuldersmerter at du må endre på treningen din? Ja ☐ Nei ☐

Gjorde dine skuldersmerter at du ikke kan spille kamp? Ja ☐ Nei ☐

Påvirket skuldersmertene dine daglige aktiviteter for øvrig (f.eks løfte, gre håret etc) Ja ☐ Nei ☐

Hadde du problemer med å sove p.g.a skuldersmertene? Ja ☐ Nei ☐

Kjente du deg støl/stiv i skulderen? Ja ☐ Nei ☐

Søkte du medisinsk hjelp for dine skuldersmerter? Ja ☐ Nei ☐

Hvis ja, hvem søkte du hjelp hos? Lege Fysioterapeut Annet

Fikk du en diagnose? Ja ☐ Nei ☐
Hvis ja, hvilken? ....

Fikk du noen behandling? Ja ☐ Nei ☐
Hvis ja, hvilken? ....

Takk for at du tok deg tid til å svare på spørreskjemaet!

Appendix IV

Protocol for testing shoulder range of motion and isometric strength

Glenohumeral rotation, external rotation strength and scapular control are risk factors for shoulder injuries among elite male handball players

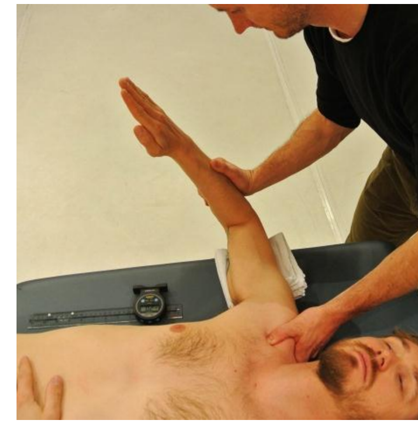
A prospective cohort study

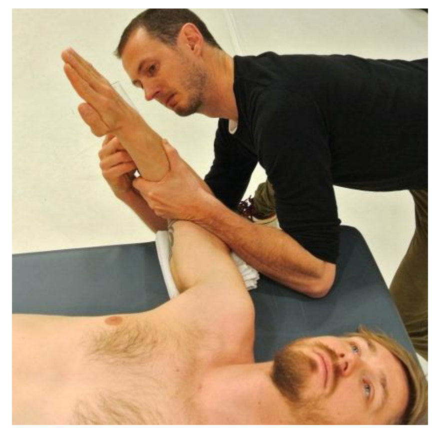
Shoulder testing protocol

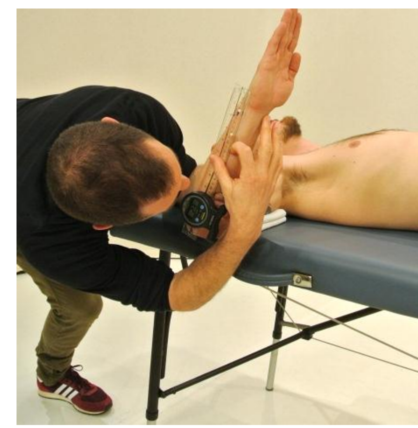
Oslo Sports Trauma
RESEARCH CENTER

Glenohumeral internal rotation range of motion

- The centre of the player's olecranon and lateral aspect of their ulnar styloid is marked
- Player lies supine with their upper arm well supported by the table
- A folded towel may be necessary to correct frontal-plane alignment of the upper arm
- The tester grips the players scapula with their thumb palpating the coracoid process and their fingers wrapped around the spine of the scapula
- The glenohumeral joint is internally rotated until the scapula begins to move into anterior rotation
- The shoulder is stabilised in this position and the angle of internal rotation is measured using a digital inclinometer
- The average of two measurements is recorded





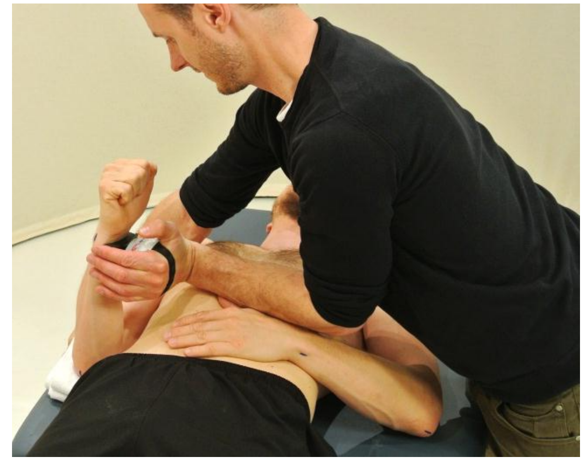


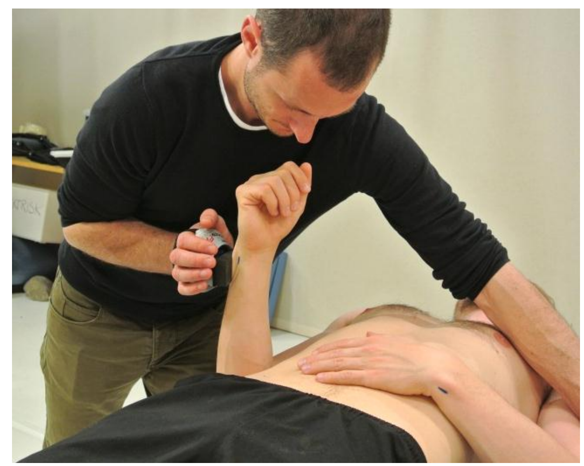
Glenohumeral external rotation range of motion

- The centre of the player’s olecranon and lateral aspect of their ulnar styloid is marked
- Player lies supine with their upper arm well supported by the table
- A folded towel may be necessary to correct frontal-plane alignment of the upper arm
- The tester grips the players scapula with their thumb palpating the coracoid process and their fingers wrapped around the spine of the scapula
- The glenohumeral joint is externally rotated until the scapula begins to move into anterior rotation
- The shoulder is stabilised in this position and the angle of external rotation is measured using a digital inclinometer
- The average of two measurements is recorded

Isometric internal and external rotation strength

- The handheld dynamometer is placed 1cm proximal to the radiocarpal joint line
- The player is passively guided through the desired movement
- The tester reaches over the player and grips the opposite edge of the table to maximise stability
- The player is instructed to build up force against the dynamometer over 3 seconds, then hold a maximal contraction for 5 seconds
- Two repetitions are performed with approximately 30 seconds rest. The best attempt is recorded





Isometric abduction strength

- A 30° angle is marked on the floor using tape to help align the player's shoulder in the plane of the scapula. Their shoulder is positioned in 30° abduction using a large goniometer
- The player's shoulder is externally rotated and their elbow is fully extended in a neutral "thumbs-up" position
- The player is given instruction to retract their scapula and instructed on the normal mistakes made during the test (shrugging the shoulder, flexing the elbow and leaning the trunk away from the tester)
- The dynamometer is placed 1cm proximal to the radiocarpal joint line
- The player is instructed to build up force against the dynamometer over 3 seconds, then hold a maximal contraction for 5 seconds
- Two repetitions are performed with approximately 30 seconds rest. The best attempt is recorded

Appendix V

The Oslo Sports Trauma Research Center Questionnaire on Health Problems

The OSTRC Questionnaire on Health Problems

Please answer all questions regardless of whether or not you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

If you have several illness or injury problems, please refer to the one that has been your worst problem this week. You will have a chance to register other problems at the end of the questionnaire.

Question 1

Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past week?

- ☐ Full participation without health problems
- ☐ Full participation, but with injury/illness
- ☐ Reduced participation due to injury/illness
- ☐ Cannot participate due to injury/illness

Question 2

To what extent have you reduced you training volume due to injury, illness or other health problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

To what extent has injury, illness or other health problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

To what extent have you experienced symptoms/health complaints during the past week?

- ☐ No symptoms/health complaints
- ☐ To a mild extent
- ☐ To a moderate extent
- ☐ To a severe extent

Question 5

Is the health problem referred to in the four questions above an injury or an illness?

- ☐ Injury
- ☐ Illness

Question 6 - Injury Area

Please select box that best describes the location of your injury. If the injury involves several locations please select the main area. If you have multiple injuries please complete a separate registration of each one.

- ☐ Head/face
- ☐ Neck
- ☐ Shoulder (including clavicle)
- ☐ Upper arm
- ☐ Elbow
- ☐ Forearm
- ☐ Wrist
- ☐ Hand/fingers
- ☐ Chest/ribs
- ☐ Abdomen
- ☐ Thoracic spine
- ☐ Lumbar spine
- ☐ Pelvis and buttock
- ☐ Hip and groin
- ☐ Thigh
- ☐ Knee
- ☐ Lower leg
- ☐ Ankle
- ☐ Foot/toes
- ☐ Other

Question 7 - Illness Symptoms

Please check the boxes corresponding to the major symptoms you have experienced during the past 7 days. You may select several alternatives; however, in the case that you have several unrelated illnesses please complete a separate registration of each one.

- ☐ Fever
- ☐ Fatigue/malaise
- ☐ Swollen glands
- ☐ Sore throat
- ☐ Blocked nose/running nose/sneezing
- ☐ Cough
- ☐ Breathing difficulty/tightness
- ☐ Headache
- ☐ Nausea
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Fainting
- ☐ Rash/itchiness
- ☐ Irregular pulse/arrhythmia
- ☐ Chest pain/angina
- ☐ Abdominal pain
- ☐ Other pain
- ☐ Numbness/pins and needles
- ☐ Anxiety
- ☐ Depression/sadness
- ☐ Irritability
- ☐ Eye symptoms
- ☐ Ear symptoms
- ☐ Symptoms from urinary tract/genitalia
- ☐ Other. *Please specify* ______________________________________

Question 9 – Time loss

Please state the number of days over the past 7-day period that you have had to completely miss training or competition due to this problem?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Question 10 - Reporting

Is this the first time you have registered this problem through this monitoring system?

- ☐ Yes, this is the first time
- ☐ No, I have reported the same problem in one of the previous four weeks
- ☐ No, I have reported the same problem previously, but it was more than four weeks ago

Question 11 – Contact with medical personnel

I have reported this problem to

- ☐ Olympic team doctor
- ☐ Olympic team physiotherapist
- ☐ Other Olympiatoppen doctor
- ☐ Other Olympiatoppen physiotherapist
- ☐ Other doctor or physiotherapist. Please state their name and workplace:

  ____

Question 12

Please use this field to send additional information about this problem to your Olympic medical team

Question 13

Have you experienced any other illnesses, injuries or other health problems during the past 7 days?

- ☐ Yes
- ☐ No