Injury Prevention in Different Sports 254

John Nyland, Defne Kaya, and Robert P. Wessel

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J. Nyland (✉)
Kosair Charities College of Health and Natural Sciences, Spalding University, Louisville, USA
e-mail: john.nyland@louisville.edu; jnyland@spalding.edu

D. Kaya
Department of Physical Therapy and Rehabilitation, Faculty of Health Science, Biruni University, İstanbul, Turkey
e-mail: defne@haceteppe.edu.tr; defne@hacettepe.edu.tr

R.P. Wessel
Division of Sports Medicine, Department of Orthopaedic Surgery, University of Louisville, Louisville, KY, USA
e-mail: rpwessel3@gmail.com

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Abstract

Even with innovative warm-up, conditioning, and rule/regulation modifications, sport injuries cannot be completely avoided. This chapter discusses sport injury prevention with consideration of intrinsic and extrinsic risk factors, inciting events, overreaching and overtraining, biomechanical and epidemiological sport injury models, primary, secondary and tertiary sport injury prevention, objectively appraising individual characteristics, and practical examples of injury prevention interventions related to specific sports.

Introduction

Participation in sport is a double-edged sword: the profound health benefits gained versus the risk of injury and the associated morbidity and costs (Klugl et al. 2010). To the casual observer, athletic injuries may appear to be accidents, purely random, serendipitous events. However, many factors may play a role before the actual occurrence of an injury (Meeuwisse 1994).

Although the complete prevention of musculoskeletal injury in sport is not possible, there are steps the athlete and the medical care team can take to minimize its likelihood and severity should injury occur. Because athletic injuries, like most disease states, are often multifactorial in etiology, examining risk factors separately without fully appreciating all potential risk factors will not yield an accurate picture of how each contributes to the condition (Meeuwisse 1994).

Intrinsic and Extrinsic Risk Factors

Important determinants for tissue load tolerance, such as material properties and ligament size, are influenced by intrinsic or internal factors such as age, sex, body size and composition, general health status, anatomical alignment, biomechanics, conditioning and skill level, maturational state, somatotype, flexibility, injury history, neuromuscular function, pre-activity warm-up level, joint flexibility, musculotendinous extensibility, training background, genetic predisposition, and physical condition (McBain et al. 2012a). Extrinsic or external risk factors include human factors such as competitor behaviors; use of protective equipment such as helmets, braces and footwear, shoe traction, and floor friction; environmental factors such as weather, playing surface type, and maintenance level (field conditions); and specific sport rules and regulations (McBain et al. 2012a) which may also influence loads. For example, helmets may attenuate loads, whereas training on a hard surface increases loading forces. The sum of these risk factors and the interaction between them may lead the athlete to sustain an injury if a particular combination of situations occurs. Last (1988) defined predisposing factors as those that prepare, sensitize, condition, or otherwise create a situation where the host tends to react in a specific fashion. Both intrinsic and extrinsic risk factors may render the athlete susceptible to injury but are not usually sufficient for injury to occur (Meeuwisse 1994). Rather, these factors interact in such a way as to make the athlete an accident waiting for a place to happen (Meeuwisse 1994).

Many knee and ankle injuries are more likely to occur on high friction floors (extrinsic risk factor) to athletes with suboptimal neuromuscular control (intrinsic risk factor). In a randomized controlled trial, Olsen et al. (2003) reported that there was an increased ACL injury risk on high friction floors for female handball players but not males indicating that there is an interaction between sex (internal risk factor) and floor friction (external risk factor), risk factors indicating that there may be a difference in the characteristics of the inciting events between sexes as well. To develop effective athletic injury prevention programs, prediction models need to account for all potential factors at the same time, not only the biomechanics associated with injury or particular internal or external risk factors considered in isolation (Meeuwisse 1994; Bahr and Krosshaug 2005). Improved postural control of the trunk and lower extremity through neuromuscular control training may help an athlete position the lower extremity more correctly prior to loading. Comprehensive information regarding potential risk factors and injury mechanisms must be evaluated to develop targeted prevention methods. This approach should be used for each specific injury type in a given sport.

Inciting Events

The final link in the maze of potential injury causation is an inciting event, which is more obviously (or visibly) related to the injury (Meeuwisse 1994). These precipitating factors are associated with the definitive onset of the injury and are almost always regarded as necessary causes. The sports medicine practitioner typically focuses on these inciting events and the mechanism of injury itself. Less attention tends to be paid to the other factors that are distant from the outcome that precede the inciting event (Meeuwisse 1994). However, in many instances these factors contribute to the inciting event.

Inciting events include specific situations that arise during play, player/opponent behavior, whole body general biomechanical factors, and joint-/tissue-specific biomechanical factors (McBain et al. 2012a). An injury occurs when the stress applied to a tissue is greater than its ability to absorb the stress. This results from complex interactions between internal and external risk factors. Consideration should be given to the number and severity of sport injuries per time of exposure (van Mechelen et al. 1992). Because it is the most apparent, however, much of the cause may be attributed to the inciting event. The inciting event is not the only component of injury causation and may or may not be the most important (Meeuwisse 1994). Many factors however may play a role in a multitude of potential injury causes, with the inciting event being the last element that should be considered (Meeuwisse 1994). Within this context, acute "more macro" injuries may have more injury causation influence on the inciting event. When this is the case, only a small contribution is required from other risk factors to produce a sufficient cause of injury. In contrast, micro-trauma or overuse injuries may have a larger number of potential causal risk factors, all of which contribute individually to a lesser extent as a series of smaller contributions (Meeuwisse 1994).

Effective injury prevention programs typically attempt to optimize the balance of applied and absorbed tissue stress. For example, the increased stress associated with abnormal lower extremity alignment may be somewhat mitigated with foot orthoses, poor proprioception or kinesthesia may be mitigated with specific neuromuscular or sensorimotor control training programs, and the increased stress associated with direct contact can be mitigated with appropriate equipment and padding (McBain et al. 2012a). Injury prevention strategies can be categorized into three basic groups: (1) equipment-related such as braces, orthoses, running surfaces, clothing, or footwear; (2) training-related such as muscular strength, power and endurance, joint range of motion, reaction time, and proprioception; and (3) rules and regulation-related which may lead to a change in the culture of the sport (McBain et al. 2012a). An example of such a change in culture is the recent National Football League and National Collegiate Athletic Association ban on same-day return to play for concussions (McBain et al. 2012b). Since 2000, the number of equipment studies has been decreasing and the number of training studies that focus on improving balance, coordination, strength, neuromuscular control, power, and mental preparation has been increasing (McBain et al. 2012b; Nyland and Lee 2013).

Bahr and Krosshaug (2005) suggested that a full description of the mechanism(s) for a particular injury type in a given sport should include information on different levels. The description of the inciting event could be grouped into four basic categories (playing situation, player/opponent behavior, gross biomechanical description at the whole body level, and a detailed biomechanical description at the joint tissue level). Therefore, the term "injury mechanism" is now expanded to represent a more comprehensive summary of the (1) essential aspects of the playing (sports) situation from a sport- and position-specific point of view, (2) athlete's and opponent's behaviors including a qualitative description of their interactions at and near the time of injury, (3) gross description of whole body biomechanics, and (4) description of joint/tissue-specific biomechanics.

Finally, it is important to understand that the event that led to injury may have actually been initiated at a distant time point to injury onset as with stress fractures (Bahr and Krosshaug 2005). With overuse or micro-trauma-related injuries, the inciting event is often less apparent. Meeuwisse (1994) suggested that the relative contribution of intrinsic and extrinsic factors differs between overuse or micro-trauma and other injury types. In overuse injuries, there is likely a greater contribution from intrinsic risk factors. For example, in running-related injuries the age and lower extremity biomechanical alignment of the athlete may predispose them to injury. The use of worn shoes and running on rough terrain (extrinsic factors) may make them more susceptible to injury. The inciting event may be running an excessive distance which leads to a stress fracture. The inciting event (excessive mileage) on its own may not be sufficient to cause injury, but rather represents the last step in a series of events leading to the index injury (Meeuwisse 1994).

Until a comprehensive description is available which includes information on all causative factors, it may be difficult to predict which factors may be modifiable through intervention. A comprehensive injury causation model must include the unique characteristics of the specific sport, position played in that sport and style of play that is in question, and consideration of the culture of the particular sport that the athlete participates.

A more precise description of the inciting event is a key component to understanding the causes of any particular injury type in a given sport. The traditional biomechanical approach to describing the inciting event needs to be expanded, integrating both qualitative and quantitative research methods to better prevent injuries (Bahr and Krosshaug 2005). To optimize prevention program success and injury risk reduction, details regarding the injury mechanism must be expanded upon. A more comprehensive model should go beyond a purely biomechanical or epidemiological explanation to also consider player behaviors and game situations.

Overreaching and Overtraining

Overreaching represents an accumulation of training and/or non-training stress resulting in short-term performance decrements with or without related physiological and psychological signs and symptoms of maladaptation where performance restoration may take from several days to several weeks (Meeusen et al. 2013). To be successful, the athlete must apply progressive overload while avoiding the temptation of combining excessive overload magnitude and/or frequency with inadequate recovery. While planned "overreaching" can enhance athletic performance following recovery through "super compensation," insufficient respect for the appropriate balance between training and recovery can lead to overtraining and prolonged maladaptations. Training can be defined as the overload used to disturb homeostasis resulting in acute fatigue, which eventually leads to performance improvement (Meeusen et al. 2013). The initial signs and symptoms of prolonged training distress such as performance decrements, psychological disturbances (decreased vigor, increased restlessness, depression, anxiety), and hormonal disturbances will occur and the athletes will need weeks or months to recover (Kreider et al. 1998). Several confounding factors such as inadequate nutrition, illness, psychosocial stressors, and sleep disorders may be present. What helps separate overtraining from overreaching is that overtraining represents "prolonged maladaptation" not only in the athlete, but in several biological, neurochemical, and hormonal regulation systems that create a sport-specific performance decrease combined with mood state disturbances (Meeusen et al. 2013).

Epidemiological Sport Injury Models: The Biomechanical Perspective and More!

Most studies that have examined sport injury risk factors have not approached the issue of etiology using a multifactorial paradigm (Meeuwisse 1994). Sport injury models can be used to account for risk homeostasis (risk compensation), changes in behavior resulting from the introduction of a safety measure (Bahr and Krosshaug 2005). For example, a skier who wears a helmet may take greater risks, such as skiing more aggressively on more difficult runs. The key point to consider with regard to biomechanical factors is that they must explain how the event either resulted in a mechanical load in excess of that tolerated under normal circumstances or reduced the tolerance levels to the point at which a normal mechanical loading cannot be tolerated (Bahr and Krosshaug 2005). Biomechanically oriented sport injury prevention models tend to dominate the literature; therefore, it is tempting to conclude that a detailed biomechanical description of these factors is more important than a detailed description of the playing situation. This temptation must be avoided as it is necessary to expand the traditional biomechanical approach when describing the inciting event if the objective is to prevent injuries (Bahr and Krosshaug 2005). McIntosh (2005) described a more complex sport injury prevention model that better appreciated factors such as the interplay between load and load tolerance, player behaviors/attitudes, training, skill level, equipment, coaching, other competitors, and the environment.

Regardless of whether a biomechanically focused epidemiological model is used to describe the interaction between the different causative factors, a precise description of the inciting event is critical (in addition to having a holistic understanding of the athlete's status at the time of the event). The term "injury mechanism" is widely used in medical literature to describe the inciting event in biomechanical terms, but its meaning is not well defined (Bahr and Krosshaug 2005). In describing a situation where a basketball player sustained an ACL injury, one study might suggest that the injury was caused by the point guard driving into the lane, then planting, and cutting to pass the ball to another player positioned closer to the basket. This description includes aspects of the playing situation and the skill(s) performed when the injury occurred. Additional information might include that the injury occurred as the player was shoved while attempting to drive past the defender using maximal effort. This description includes aspects of the athlete's inherent characteristics and behavior as well as the opponent's behavior that may have triggered their actions (Bahr and Krosshaug 2005). A general biomechanical description might be that the knee injury occurred as a result of a rapid sideways knee translation when the foot was planted on a high-friction floor surface. A more detailed biomechanical description might be that the knee injury occurred as a result of large external valgus and external rotation knee moments in combination with a translatory tibial shift relative to the femur (Bahr and Krosshaug 2005). The description could range from information related to the general or specific playing situation, player, and opponent behaviors to more or less detailed biomechanical descriptions of joint motions and loads. Optimally each of these factors (and perhaps some others not yet identified) may need to be considered. If multiple factors are capable of producing a particular condition outcome, the minimum set of factors required to produce that outcome are referred to as a sufficient cause (Meeuwisse 1994).

Primary, Secondary, and Tertiary Sport Injury Prevention

Primary prevention refers to health promotion and injury prevention among athletes who have never experienced a serious injury (Guide to Physical Therapist Practice 2001) (Fig. 1). This is what

Fig. 1 Pre-sport training practices, appropriate nutrition, and recovery may be sufficient primary prevention steps for a high school basketball athlete

many ACL injury prevention strategies are designed to do. Secondary prevention refers to early diagnosis of an injury, its initial treatment, and the steps taken to control or otherwise reduce the risks of re-injury after treatment has ended. An example of this is represented by criteria-based return to sport training for football players following ACL reconstruction (Fig. 2). Tertiary prevention refers to focused condition and rehabilitation to correct, control, or otherwise manage an existing disability to enable continued activity of daily living and sport performance function at a high level. An example of this includes the many interventions designed to preserve and enhance the shoulder function of a Paralympic archer with spinal cord injury who underwent bow arm rotator cuff repair (Nyland et al. 2000) (Fig. 3). Steps to preserve shoulder function during both athletic activities, activities of daily living including sliding board transfers, and wheelchair locomotion in addition to providing effective long-term management of other impairments associated with

Fig. 2 A college football running back who is returning from multiple knee ligament injuries must follow a more cautious, criteria-based progression for secondary injury prevention to be effective

paraplegia are directly related to both the quality of life and the life expectancy of the Paralympic athlete.

Objective Appraisal of Individual Characteristics

There is value in performing an objective self- and peer-assessment of all potential sport injury-related factors and how their confluence may contribute to injury likelihood. It is known that athletes who sustain a serious knee injury are more likely to return back to competitive sports when the sport has a definitive season and off-season (Ardern et al. 2011). It is also known that having a singular perceived role as an "athlete," particularly a single sport athlete can be problematic when a serious injury arises because the individual may not have developed the diverse coping, self-efficacy, and resilience building strategies that can be obtained from experiencing a variety of sport and movement experiences (Brewer and Cornelius 2010; Mostafavifar et al. 2012a). Likewise, by not connecting one's self-value to a singular role such as "soccer athlete," but to multiple roles such as "student," "musician," "dancer," "artist," "hunter,"

Fig. 3 A Paralympic archer with spinal cord injury who is recovering from a "bow arm" rotator cuff repair requires consideration of chronic impairments associated with the initial spinal cord injury-induced paraplegia in addition to maintaining non-impaired upper extremity strength, extensibility and neuromuscular control to enable athletic performance, and safe wheelchair locomotion and transfers. Tertiary prevention of potential long-term upper extremity degenerative changes associated with chronic weight bearing is vital

singer, etc., it may be easier for the injured athlete to recover following a serious sport injury. Recovery may be easier because in the second instance the onset of sport is not perceived as potentially being the end of a singular role (Brewer and Cornelius 2010). A wide range of sport activities during youth will promote diverse relationships and experiences in children and adolescents. As adolescents develop into young adults, having a breadth of experiences in differing sports (and other activities) can expand their adult physical activity options and foster an intrinsic interest in lifelong participation for recreation and health. Beyond the psychological benefits, youth who participate in multiple sports can gain an expanded interest and identity from their diverse experiences and may be less likely to be drawn into a specific sport culture that is focused more on winning than on overall child development. A variety of sports are needed for the young athlete to develop comprehensive motor skills. Diverse sport participation (and other things besides sports) along with use of a neuromuscular training regimen to offset motor skill deficit reduction may help reduce the likelihood of sport-related injuries in young athletes and enhance coping skills should injury occur. The benefits of a comprehensive program would include preparatory conditioning, enhanced sport performance, reduced injury severity and frequency, and reduced burnout. Cumulatively, it is not surprising that the most elite athletes are most commonly those who specialized in sports later in life (Moesch et al. 2011). There is a dynamic nature of the self in the context of sport supporting a view of adjustment to sport injury and its concomitants as a process involving personal, situational, cognitive, behavioral, emotional, and recovery outcome variables (Brewer and Cornelius 2010).

Athletes may decrease their self-investment in sports when they encounter circumstances that threaten their performance in the athlete role (Brewer and Cornelius 2010). Such divestment of athletic identity can be interpreted as a form of self-protection, a powerful human motive to maintain a positive self-concept. From a self-protection perspective, decreasing one's athletic identity after ACL reconstruction could help preserve self-esteem in the face of a formidable threat to short- and potentially long-term sport participation. Greater decrements in the athlete role would be expected for individuals who are experiencing a slow postoperative recovery and therefore an elevated level of threat to sport involvement (Brewer and Cornelius 2010). The divestment of athletic identity in response to the physical challenges of surgery and rehabilitation, even in the short term, may be associated with the benefits of improved self-esteem and emotional functioning.

As they likely depend on the salary they obtain playing their sport to support their family and lifestyle, injury to the professional soccer athlete is known to be associated with greater depression and emotional distress than injury to the recreational soccer athlete (Oztekin et al. 2008). For financial reasons these individuals have considerably more at stake should they not be able to successfully return to competitive play at the level they were capable of prior to the injury. Given the relatively small percentage of athletes that attain the professional level of competition and the similarly short length of time that many continue to participate at that level in any sport, it is paramount that they begin to plan for the instant when they can no longer play their chosen sport before or soon after becoming a professional athlete.

Practical Examples Related to Sport Selection (Soccer, Volleyball, Basketball, Tennis, or Team Handball)

Conventional taping/strapping and bracing can help restrict undesired, potentially harmful motions and allow desired motions (Verhagen et al. 2004; Swirtun et al. 2005). Conventional taping is generally used as a preventive measure in high ankle injury risk activities such as basketball and volleyball. Simple neoprene knee sleeves may improve joint proprioception; however, they provide little mechanical support (Swirtun et al. 2005). The addition of mechanical brace components may help control tibial rotation during high-demand athletic activities (Giotis et al. 2013). A systematic review by Mostafavifar et al. (2012b) found insufficient evidence to support kinesio taping as is often used following shoulder injury in sports with overhead movements such as volleyball, tennis, and team handball. However, out of 727 papers found on initial search, only 6 met study inclusion criteria of English language, randomized controlled trial, cohort, or case-control design and of those only two involved shoulder treatment. One of these found insufficient evidence to indicate that kinesio taping decreased shoulder pain and disability (Thelen et al. 2008), while the second suggested that it may provide short-term pain relief (Kaya et al. 2011). The review paper authors concluded that perceived benefits cannot be completely discounted as few of the reviewed studies displayed high research methodological quality.

Shock-absorbing insoles can reduce peak force magnitude and loading rates during running and reduce ground reaction forces transmitted through the foot to more proximal structures. Studies have reported the effectiveness of medial post (Joseph et al. 2008) and foot orthosis (Jenkins et al. 2009, 2011) use for controlling knee valgus, transverse plane knee rotation, and frontal plane hip motion, known to be related to ACL injury among healthy active female subjects (Hewett et al. 2005). Athletes who participate in soccer, basketball, and team handball are more likely to sustain serious knee injuries compared to volleyball or tennis players. Tennis, team handball, and volleyball players are more likely to sustain overuse upper extremity injuries. Knowing the injury frequency likelihood when selecting sports can help drive early injury prevention practices. Neuromuscular training programs can also reduce the frequency and severity of athletic knee and ankle injuries (Gilchrist et al. 2008; LaBella et al. 2011; Longo et al. 2012). Ideally, injury prevention training programs are multifaceted addressing many aspects that could potentially increase injury risk such as impaired balance, strength, postural awareness, and poor playing technique. The number and quality of training intervention strategy studies are on the increase (McBain et al. 2012b). Interestingly, the number of studies that focus on neuromuscular strength and power is increasing at a similar rate as balance and coordination studies, but with a 5-year delay (McBain et al. 2012b).

A number of interventions appear to be effective in preventing lower extremity injuries in female soccer athletes (Soligard et al. 2008) and in young female basketball and volleyball players (LaBella et al. 2011). The Prevent Injury and Enhance Performance or "PEP" strategy can reduce ACL injuries in young amateur female soccer athletes (Gilchrist et al. 2008), and simple lower extremity stretching and strengthening exercises substantially reduced the incidence of anterior knee pain among a young (median age = 19.7 years) military population during physical conditioning (Coppack et al. 2011). A systematic literature review by Herman et al. (2012) found that integrated neuromuscular warm-up factors including stretching, strengthening and balance exercises, sport-specific agility drills, and landing technique instruction reduced lower extremity injury in young amateur female athletes and in male and female military recruits when the strategy was applied consistently for longer than three consecutive months. Proper injury prevention training requires that the athlete perform simple, practical sport-specific movements with cognitive focus, not merely going through the motions (Longo et al. 2012; Nyland 2012). Clinic-based "virtual function" assessments often provide a poor simulation of actual sport movement challenges, particularly when fatigue and other stressors are not introduced. All too often, imposed clinical movement tasks do not remotely simulate the actual demands of competitive sports. Actual sport function requirements consist of considerably greater multisystem function than the shallowness and limited variability provided by many clinical preparation programs.

Summary

Injuries occur too frequently during sport participation. By improving our understanding of factors that contribute to inciting events, including the cultural differences of various sports, steps can be taken to decrease injury severity and frequency. Rather than focusing primarily on the inciting event at the time of injury, clinicians are reminded to take a more comprehensive view of the athletes' history, lifestyle, training practices, diet, and other variables which over time may have contributed to the index injury.

Cross-References

- ▶ Anterior Cruciate Ligament Injuries: Prevention Strategies
- ▶ Concussion in Sports Traumatology: Future Trends
- ▶ Factors Affecting Return to Sport After Anterior Cruciate Ligament Reconstruction
- ▶ Handball Injuries: Epidemiology and Injury Characterization
- ▶ Orthopedic Research in the Year 2025

► Planning the Medical Aspects of a Sports Event
► Prevention of Childhood Sports Injuries
► Prevention of Knee Injuries in Soccer Players
► Return to the Field for Football (Soccer) After Anterior Cruciate Ligament Reconstruction: Guidelines
► Studies on Orthopedic Sports Medicine: New Horizons

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