Figure 9.1. Typical injury mechanism for acromioclavicular joint dislocation: fall directly on the lateral side of the shoulder

around the shoulder or a hematoma. More severe trauma may result in a clavicle fracture, a contusion or dislocation of the acromioclavicular joint (Figure 9.1) or fractures of the upper humerus or (rarely) the glenoid. Falls are common in cycling (when going over the handle bars) and skiing. Blows are common in American football (i.e., when a player gets low and uses the shoulder to take an opponent or gets tackled and lands on their shoulder) and ice hockey (when the player hits an opponent or the boards with the shoulder). Compression happens in ice hockey, when the player skates alongside the boards and is hit by an opponent. Because of the high velocity, the player is subjected to an enormous compression force between the opponent and the fence. A similar compression occurs in American football when being tackled.

The resulting injury depends on the exact direction of the force and the anatomical structure that is subject to the trauma. If the acromion is hit in a skeletally mature athlete, an injury to the acromioclavicular joint is most likely, if the clavicle is hit a clavicular fracture is likely, and if the upper arm is hit, a proximal humerus fracture is likely to occur. In the older athlete, fracture of the clavicle or the humerus is more likely to happen than dislocation of the acromioclavicular joint, as the bone becomes weaker with age. Acromioclavicular and sternoclavicular joint injury is the result of a lateral force. The brachial nerve plexus can be stretched by a direct blow to the superior side of the shoulder, anterior or posterior sudden, forceful pushes to the shoulder or pulls of the arm, and may lead to a "burner," that is, diffuse pain of the shoulder and arm, caused by injury of one or several nerves, though usually the upper trunk (Figure 9.2). This typically happens if a player uses the shoulder to butt other players.

Indirect traumatic injuries

Indirect injuries are caused by transmission of force through the arm. Fall on an outstretched, flexed arm may result in a Bankart-like lesion of the posterior capsule, but most often in acromioclavicular joint damage, as the posterior shoulder capsule is very tight and transmits the force to the scapula. The injury after fall on an outstretched, abducted arm depends on the amount of abduction: below horizontal a SLAP lesion can occur, above horizontal a Bankart lesion/dislocation is more likely (where the labral or cartilage rim injury is in the anterior lower quarter of the socket). Fall on extended arm results in a SLAP or Bankart lesion or an acromioclavicular-joint lesion. A force that involves rotation of the arm, that is, blocking a throw or falling on a slightly abducted/outwardly rotated arm with flexed elbow applies tremendous force on the rotator cuff and the accelerating muscles. This can be an eccentric or a concentric type of load and result in a muscle/tendon sprain, rupture of a tendon, avulsion of a tendon, or fracture

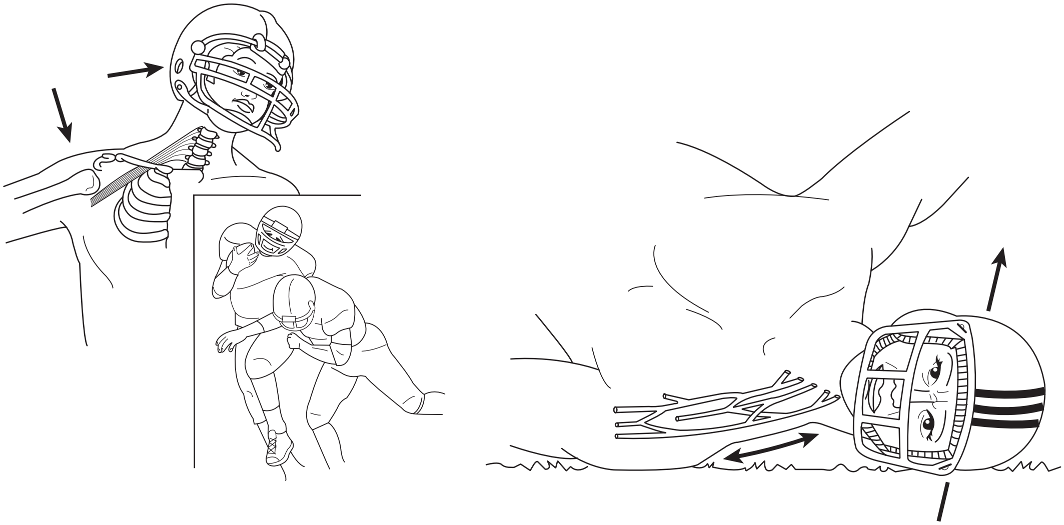


Figure 9.2. Typical injury mechanisms for "burners:" stretching of the brachial nerve plexus

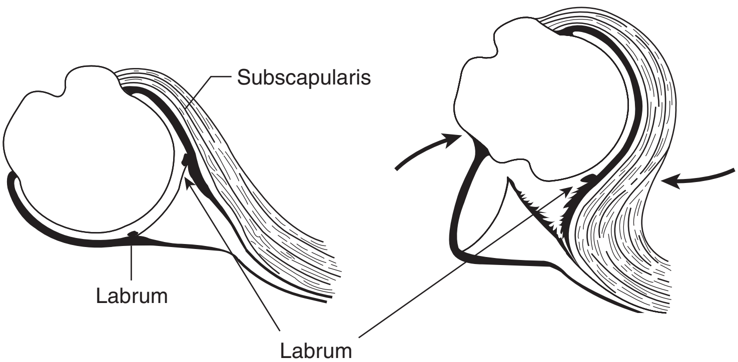


Figure 9.3. Dislocation of the humeral head results in a Bankart lesion (avulsion of the labrum and the glenohumeral ligaments from the anterior glenoid)

at the site of insertion. If the arm is positioned behind the shoulder joint, blocking can result in an anterior translation of the humeral head and an injury of the anterior structures of the glenohumeral joint, typically a Bankart lesion (Figure 9.3). This injury mechanism is quite common in body building/strength training as a result of an extreme extension of the arms during bench press or downward pulls. If the arms are extended to more than 0° during these exercises (i.e., if the arms are moved behind the shoulder joint), there is extreme tension on the anterior structures of the glenohumeral joint, in particular the labrum and glenohumeral ligaments. If the internal rotators of the arm fail to resist the load, this may cause a Bankart or SLAP lesion or stretching of the anterior capsule. Incidents that make a sudden, powerful inward rotation of the arm combined with flexion of the elbow necessary, if to avoid an object from hitting the head, can rupture the lateral portion of the coracohumeral ligament (which covers the biceps groove between the lesser and greater tubercles and holds the biceps tendon in the groove) as well as the upper part of the subscapularis tendon insertion on the lesser tubercle. This results in a biceps tendon dislocation or subluxation.

It is the least strong tissue that is damaged during trauma. In children, the epiphyseal growth plates and bones are soft, and avulsions of the bony attachment of a ligament or capsule rather than rupture of the soft tissue is more likely to happen than in adults with stronger bones. Also epiphysiolysis of the greater tubercle or the neck of the humerus can happen. In young and middle-aged athletes, the soft tissue is usually the weakest. In athletes above 60 years the natural decrease in bone mineral content makes fractures and avulsions more likely to happen, but tendons—in particular the rotator cuff tendons and the long head of biceps—also weaken with age, and ruptures can happen after minor trauma or almost spontaneously, such as during tennis or badminton.

Overuse injuries

Overuse injuries can be caused by a repeated, powerful force to a structure through sports (*extrinsic factors*). In most cases this is the result of an increase in training intensity, introduction of a new technique, or new equipment, etc. The load on soft tissue structures exceeds capacity of the tissue, leading to inflammation and pain. This acute condition is easily reversible, if the load is adjusted to the capacity.

Weight lifting applies enormous forces through the acromioclavicular joint, and swimming applies a huge number of rotations in the acromioclavicular joint, both mechanisms resulting in inflammation and gradually degenerative disease in the acromioclavicular joint.

A very specific injury develops because the best performance in throwing is achieved if the shoulder is cocked, that is, positioned in full abduction and external rotation (Figure 9.4). This motion is naturally stopped by collision between the undersurface of the supra- and infraspinatus tendons and the superior labrum. Repeated collisions with large force result in fraying of both structures and stretching of the inferior glenohumeral ligaments (resulting in glenohumeral instability and secondary impingement) (Figure 9.5).

It is not obvious that repeated use of the rotator cuff in forceful tasks during sports results in wear of the rotator cuff/long head of biceps. Such changes may more likely be caused by repeated minor traumas with smaller, partial ruptures.

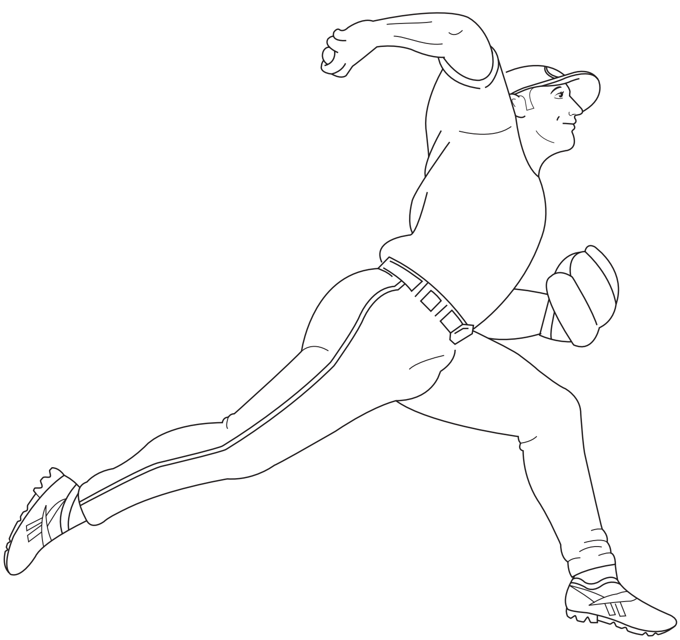


Figure 9.4. In throwing the arm is taken into full abduction and outwards rotation, which result in internal impingement and applies enormous stress to the anterior shoulder capsule

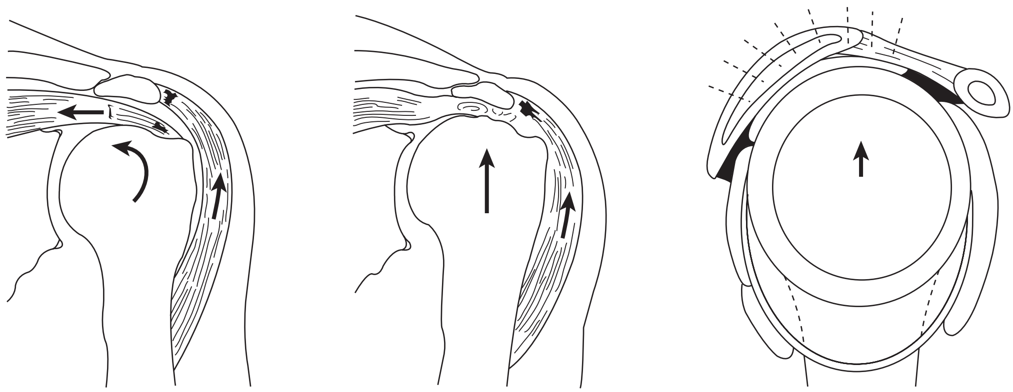


Figure 9.5. Mechanism of secondary impingement: the humeral head is elevated and the supraspinatus tendon is compressed (a) Natural situation where the rotator cuff muscles and the passive stabilizers keep the humeral head centered in the glenoid during motion and counteract the proximal pull of the deltoid muscle, allowing for shoulder rotation. (b) and (c) If the dynamic and passive stabilizers of the humeral head fails (due to rotator cuff fatigue), the deltoid muscle pulls the humeral head proximally, resulting in impingement of the rotator cuff between the humeral head and acromion.

Overuse injuries can also be caused by preexisting, less optimal conditions, or by dyscoordination/lack of dynamic stability in the shoulder and thoracoscapular junction (*intrinsic factors*). Laxity of the glenohumeral joint (which is seen in 10% of the population, represented as a large sulcus sign) is compensated for by activation of the rotator cuff muscles, when the athlete is using the arm in activities, which are dependent on stability. If these muscles are not strong enough for this work, then either the muscles are overused (resulting in tendonitis and tendinosis of the tendons and muscle pain) or the humeral head is not positioned correctly during the activity (resulting in painful stretching of the glenohumeral ligaments and the capsule). The thoracoscapular junction is the base of the arm. Insufficient stability of this is caused by relative weakness of the rhomboids and serratus anterior (pressing the scapula against the thoracic wall), resulting in compensating, painful dysfunctions in other muscles. Dyscoordination of the scapula in throwing or overhead activities is most often caused by weakness or fatigue of serratus anterior and trapezius—both muscles are responsible for the elevation of acromion during overhead activities, and if this motion is delayed or insufficient, the acromion presses against the humeral head, resulting in impingement of the supraspinatus tendon and inflammation of the subacromial bursa (Figure 9.5). Overuse injuries caused by these preexisting conditions are seen in throwing sports (repeated powerful activities to the extreme ranges of motion), swimming (repeated activities), weight lifting (powerful activities), and body building (powerful activities and a risk that only the accelerating muscles are body built).

Pain

Pain in the shoulder has great influence on the function of muscles. The activity of the agonist for the painful motion is reduced under dynamic conditions, probably as a reflex-like reaction, and in some cases the antagonist activity is increased. Also, motion patterns are changed to avoid pain. This happens in any painful condition, either after a trauma or during overload, leading in itself to dyscoordination. In this way, a self-perpetuating process may be initiated.

Protective equipment

The use of protective equipment can in some cases cause injury. It is obvious that if a hard shoulder protector is used by a player to butt others, it may give rise to traumatic injuries on other players. Protective devices may also give the athlete a sense of security, prompting them to play more aggressively, leading to injury to themselves and others.

Strangely, the use of wrist guards by snowboarders is connected to an (insignificant) increase of injury in elbow and shoulder (Hagel et al., 2005), but the injury mechanism is unknown.

Identifying risks in the training and competition program

In sports with a season, the athletes may be less fit at the beginning of the season. The smaller muscles (including the rotator cuff muscles) are at higher risk than the larger muscles to lose strength. A mismatch between the shoulder muscles can often be identified as described earlier, but smaller changes, that become important with 50 or 100 repetitions, may be difficult to demonstrate clinically. For example, the rotator cuff muscles may fatigue after 25 hard throws, whereas the larger muscles can easily do 100. This mismatch may also occur later during the season, because the larger muscles adapt more easily to increasing load. Thoracic kyphosis may increase as the shoulders rotate anterior and inward due to strong latissimus and pectoralis major muscles, and the scapula is rotated downward due to the pectoralis minor muscle, both decreasing the subacromial space and increasing the risk of impingement.

It is therefore essential that the training program contains a balanced amount of exercises all through the season. It is not uncommon to concentrate on maximum efforts in function (strength) and coordination, and only do very demanding training. This will leave the weaker and smaller muscles behind. Warm-up, which should start every training session, activates all structures (muscles, tendons, ligaments, joints) as well as the psyche (concentration and awareness, which should not be neglected). The structures become ready for maximum work, and the maximum effort training is suitable after warm-up. All athletes know that after having performed maximum training for a while, either some structures fatigue or the athlete loses concentration and awareness. Instead of ending training abruptly from the heavy exercises, lighter and easier activities, that all structures and the psyche can participate in, should complete the training session. In this way, no structure is lost due to fatigue. Also, if just one structure is not participating, the heavy exercises should not be continued. It is common to continue until complete fatigue, but this leads to a high risk of losing the weaker structures.

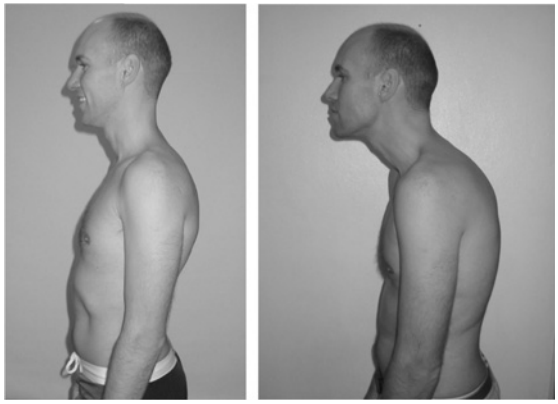


Figure 9.6. Different statures. Left: Normal stature. Right: Extended thoracic kyphosis and protracted shoulder, increased lordosis of the cervical spine

That mismatch between muscle groups is common was shown in a project, where 2000 m swimmers were tested for scapular stability by wall-push ups at several swimming distances. After 500 m 36% had winging of scapula, after 1000 m this was seen in 79%, and after 1500 m in 93%.

Even though we do not walk on our shoulders, turf changes may affect the risk for shoulder injury. In tennis, the speed and force of the ball changes from slow and weak on the relatively soft outdoor ground, particularly clay surface, to fast and forceful on hard indoor courts. This increases the need for strength, fast reaction, precision, and coordination markedly, and if the player has not prepared for this through training, overuse injury and traumatic lesions to muscles, tendons, etc. may occur. This is naturally also the case if equipment is changed, for instance, if tension of the strings in the racket is changed or another type of tennis ball is used.

Preventive measures

In theory, there are many ways to prevent traumatic and non-traumatic shoulder injuries. Some

Table 9.4 Injury prevention matrix applied to shoulder injury prevention: potential measures to prevent injuries.

	Pretrauma	Trauma	Post-trauma
Athlete	Assure glenohumeral and thoracoscapular stability Avoid "black holes" in muscular performance Throwing technique Caution if shoulder is painful Prevent falls: only sport within your own limitations, avoid risks (off piste, skiing in bad snow/weather conditions) Prevent huddling (bicycling)	Training status Falling techniques Reduce and restructure training if shoulder is symptomatic Avoid loading of the arm, while it is behind the shoulder	Rehabilitation
Surroundings	Playing rules (forbid body checking, tearing, or blocking of arm)	Breakaway bases Soft fences	Emergency medical coverage Physiotherapist instruction
Equipment	Caution if equipment is changed (other characteristics)	Shoulder pads Neck roll	First aid equipment

of these are listed in Table 9.4. Unfortunately, only one of these methods has been investigated for effectiveness.

Preventing traumatic injury

Shoulder pads can theoretically spread the force from an impact over a large area of the body and absorb energy (just like a bicycle helmet). There are no studies that prove that this can actually reduce the number or severity of shoulder injuries caused by direct blows, and hard shoulder pads have the drawback that they can hurt other players, particularly if they are used to butt others. In American football, shoulder pads protect the shoulder, dissipating the forces that would otherwise be placed on the acromioclavicular joint or the sternoclavicular joint during an axial load. Proper falling mechanics can also be taught to potentially lessen the direct impact placed across the shoulder joint by learning to roll when landing from a fall, rather than landing directly on the shoulder. Cervical orthoses are used to prevent injury to the neck and the brachial plexus ("burners"). In a laboratory setting they can be shown to reduce hyperextension of the neck, but lateral bending—which is assumed to be a major cause of nerve injury—is not consistently reduced, and the clinical relevance remains to be proven.

Head-first and diveback sliding techniques in baseball and softball can result in upper extremity injuries. But changing of techniques (e.g., banning sliding or forbidding head-first/diveback sliding) is impractical and unsatisfactory to players, and instructional courses regarding injury prevention have proved ineffective (players did not attend) (Janda, 2003). The only studies on injury prevention in softball are the breakaway base studies (Janda et al., 1988; Pollack et al., 2005).

Injury prevention strategies like protective equipment, rule changes, preseason and season prevention interventions, safety measures, better coaching, education and a social awareness have been recommended to reduce sports injuries in children (Demorest & Landry, 2003), but none of these strategies have been shown to be effective.

It has been suggested that extrinsic factors may be positively modified to reduce collision injuries and falls by using deformable walls and padded back stops as well as maintaining fields appropriately, however this has not been supported in the literature. Another statement modifying intrinsic risk factors, such as better coaching techniques as well as stretching and conditioning programs have been purported to benefit players in the prevention of their injuries, though again, this has not been objectively supported in the literature.

It has been suggested, that injuries from skiing and snowboarding can be prevented by "interventions in education and technique, conditioning and equipment and environment" (Kocher et al., 1998), but this remains to be proven. Koehle et al. (2002) states that skiing injuries to the upper extremity can be prevented by proper poling techniques and avoidance of non-detachable ski pole retention devices, as well as through specific programs focused on techniques to prevent falls. A positive effect of these interventions on injury risk remains to be proven, though. Neither traditional ski instruction nor preseason conditioning has demonstrated any positive effect (Koehle et al., 2002).

Theoretically it would to prevent some traumatic injuries if the athlete only did sports within the limits of his/her personal qualifications or physical condition, and avoided risky situations (like skiing off piste, skiing in bad weather conditions, huddling in bicycling, etc.). Also the rules can be used to prevent injury, for example, by forbidding body checking, tearing, or blocking of the arm.

Preventing overuse injuries

The thrower's paradox is that functional stability is a key basis for performance, while at the same time performance is dependent of full mobility. Therefore stability cannot be achieved by tightness, but relies mainly on muscular coordination and strength.

To some extent the training programs are the same for preventing overuse shoulder injuries and for treating symptomatic shoulders. The strategy is also the same: training should always address all structures and all functions (strength, stability, flexibility, coordination, core stability). In addition, the athlete is tested for possible risk factors (as described earlier) and the standard training program is adapted individually to compensate for "black holes." In addition, when treating symptomatic shoulders, the physiotherapist has knowledge of the condition of the tissues that suffer, and must modify the programs further in relation to this.

The standard training program will typically contain the elements listed in Table 9.5. Traditional body building of muscles that are used to create power is often not necessary, as strengthening of these muscles often follows from the specific sports activities.

The strength of the rotator cuff muscles is trained either with a rubber band (which is very handy, as it can be brought everywhere) or weights. The athlete should mix power training (with sufficient weight, that only 6–10 repetitions leads to fatigue) and endurance training (less load, where the athlete can perform 20–25 repetitions). The specific exercises are shown in Box 9.2.

Table 9.5 Standard shoulder training program.

Prophylactic training of stabilizing muscles:
• Glenohumeral stability: the rotator cuff muscles • Thoracoscapular stability: the serratus anterior and trapezius musles • Training of coordination • Training of thoracic extension • Training of the rest of the kinetic chain (core stability, knee placing training, etc.) Stretching to prevent tightness of: • The posterior capsule • The rhomboid muscles • The latissimus dorsi muscle • The pectoralis minor muscle

Serratus anterior and trapezius are the muscles that lift scapula during abduction, flexion, and throwing, and they are often overruled by, for example, the levator scapula muscle. The trapezius should be trained in order to maintain scapular stability and mid-thoracic stability of the spine. The serratus anterior muscle can be trained with side bridge and wall-press exercises as well. The serratus anterior and trapezius muscles in addition to the other scapular stabilizers are trained with side bridge exercises.

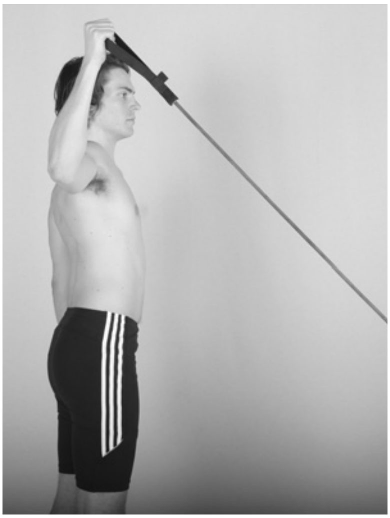
Balancing a fit-ball or a racket are two of the most demanding exercises for coordination. Thoracic extension is trained by leaning back over the back of a chair or laying on the back on a fit-ball. Just like it is much more difficult to manipulate a heavy load if you are standing in loose sand, it is difficult to make a powerful throw, if the body is not a strong, supportive basis. Therefore core stability training is also a part of basic shoulder training.

Core stability training is part of many of the exercises previously described and trains the transversus abdominis muscles, the other abdominal muscles (including diaphragm), the multifides, and a number of other spinal muscles. Core stability is obtained by pulling the umbilicus toward the third lumbar segment, flattening the abdominal wall.

Strong muscles tend to shorten and change the resting position of the shoulder. This is also the case with the posterior capsule. To avoid this, stretching should end all training sessions.

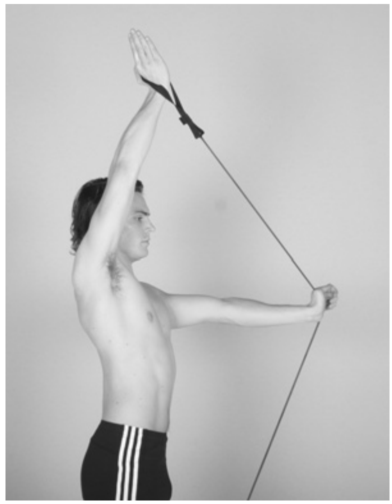
Box 9.2 Training program to prevent shoulder problems

Rotator cuff strengthening exercises
Use a rubber band. The athlete in standing position (keeping core stability) holding a rubber band in his right hand doing lateral and medial rotation. The scapula must be held stable and the humeral head must be kept from gliding anterior. The elbow must be kept in the scapular plane during exercises. When doing lateral rotation the rubber band comes from inferior and when doing medial rotation from behind the athlete at shoulder level. The exercise can be progressed by using a harder rubber band.



Training of the trapezius and the opposite serratus anterior muscles
In the standing position the athlete ties a rubber band around the left foot and holds the other end in the right hand. By elevating his right shoulder, he is training the upper part of trapezius (also called Trapezius 1). When flexing the right arm further posterior, he is training the middle and lower parts of trapezius (also called Trapezius 2 and 3). At the same time the left arm and shoulder can grab the rubber band and be pushed forward, in order to train the left serratus anterior muscle.

During these exercises the thoracic extension can also be trained by lifting the sternum. The lumbar spine must be kept stable.



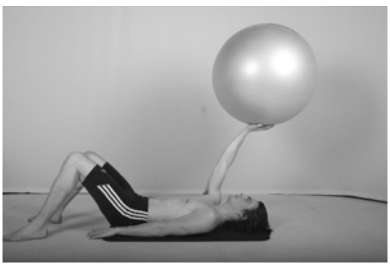
Training of the serratus anterior and trapezius muscles
The athlete is sidelying on his right elbow maintaining core and scapular stability, holding his left arm in 90º of flexion/abduction while rotating his body and reaching as far as possible. The exercise can be progressed by holding a weight in the left hand.

(*Continued*)

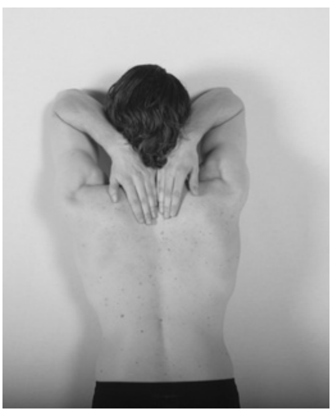
Box 9.2 (Continued)

Training of coordination with a racket
The athlete in standing position is balancing a racket on one finger without moving his feet and constantly changing the position of the arm. Exercise should be performed for 3 min.

Training of coordination with a fit-ball
The athlete laying on the floor balancing a fit-ball on his hand while changing position of the arm into flexion/extension and abduction/adduction. Exercise should be performed for 3 min.



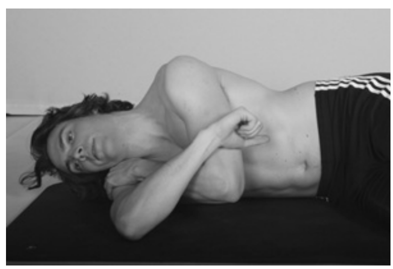
Training of thoracic extension I
Athlete standing with his elbows against a wall with his hands fingers placed around a segment of the thoracic spine making extension of the thoracic spine while the lower back is kept stable.



Training of thoracic extension II
The athlete is lying on his back on a fit-ball with his arms over the head rocking forward and backward, mobilizing the thoracic spine in passive extension.

Training of thoracic extension III
Athlete sitting on a chair leaning backward over the back of the chair mobilizing the thoracic spine into extension.

Stretching of the posterior capsule and outward (lateral) rotators
The athlete is side-laying with his right arm in 90° of flexion. The left arm presses the humeral head posterior and inwardly (medial) rotates the right arm at the same time. Each position should be kept for 40 s.



(*Continued*)

Box 9.2 (Continued)

Stretching of latissimus dorsi, the rhomboids muscles, and other inward rotating muscles
The athlete is standing in a corner doing wall-slide. By elevating the arms while keeping the scapula stable and not allowing any inward rotation of the arms, the muscles are stretched. Each position should be kept for 40 s.

Stretching of the pectoralis minor muscle
The athlete standing in a doorway with his right arm in 180° of flexion and his elbow against the door-frame, leaning his body forward to stretch the pectoralis minor muscle. Each position should be kept for 40 s.

The elements of this basic, prophylactic training program can be adjusted depending on the finding of "black holes" in the screening of the athletes.

Proper throwing mechanics and limiting the number of pitches and innings thrown are crucial for prevention of injury, particularly in the growing athlete. Control, not speed, should be emphasized in training regimens. In addition, educating coaches and players about appropriate stretching, strengthening, conditioning, and proper throwing mechanics is vital. The literature on this topic has fortunately resulted in published guidelines that limit the number of innings that young pitchers are allowed to pitch per week. The American Academy of Orthopedic Surgeons recommends limiting pitches to about 4 to 10 innings per week, 80–100 pitches maximum per game, and 30–40 pitches per practice session (Tables 10.7 and 10.8).

It has been suggested that certain pitching, batting, and fielding techniques might be related to injury, in particular the underarm technique during softball pitching (Flyger et al., 2006). This is based on biomechanical and not clinical studies.

Shoulder problems caused by overloading during the golf swing can theoretically be prevented by a warm-up program. Overuse injuries are more common in golfers that do not perform a warm-up program, but the effect of the program has never been studied in a regular trial (Fradkin et al., 2005).

Cushion grip bands have been proven to reduce impact shock and vibration transfer in tennis racquets. This could reduce the load on elbow and shoulder and positively influence the risk for overload injuries, but the effect remains to be proven.

Strength training

In athletes, strength training of the shoulders should not be performed without the basic shoulder training program, which is described earlier. Without the basic program, there is an obvious risk of creating mismatch between muscles.

Strength training can be performed after standard principles as high load (maximum 10 repetitions possible) to increase power or as low load (many repetitions) to increase endurance and flexibility.

Moving the arm posterior to the shoulder joint (shoulder extension) should always be avoided, as this is unnecessary to achieve the full effect of strength training and results in potentially injurious large stresses the anterior structures of the glenohumeral joint. Bench press is typically an exercise in which the arms are quite often moved behind the shoulders, creating anterior pain in the shoulder.

Getting back after shoulder injury

The aim of physical therapy after shoulder injury is to relieve pain, expedite the return of the athlete to play, and most importantly, to prevent new injuries before they develop. Stretching is important to establish and maintain full range of motion, especially in patients with tight posterior capsules with limited internal rotation. "Sleeper stretches" are stretching maneuvers which are effective in stretching the posterior capsule, and prevent internal impingement associated with GIRD. They are performed with the athlete lying on the affected side, with the shoulder abducted 90º. Gentle constant pressure is applied by the opposite arm, pushing the affected shoulder into internal rotation.

During the acute phase of tendinitis, exercises should be performed below shoulder level to avoid rotator cuff outlet impingement, with gradual progression as symptoms decrease. In the majority of cases, non-surgical treatment allows gradual return to sport.

A strengthening program is instituted to increase strength in the rotator cuff as well as in the scapular stabilizers to provide dynamic glenohumeral stability. Both concentric and eccentric exercises are included. Improper throwing mechanics also must be corrected. Throwing athletes are allowed to return gradually to throwing once stability, strength, and endurance have improved (usually within 3 months). Most will be able to return to their prior level of activity in 6 months.

Swimmers tend to develop tightness in the pectoralis minor, which leads to a protracted shoulder posture. This decreases the subacromial space and contributes to outlet impingement syndrome. This may be prevented by stretching the pectoralis minor.

Wrestlers tend to strengthen their anterior shoulder and chest muscles disproportionately in relation to their periscapular and back muscles, resulting in a protracted shoulder posture. This also decreases the subacromial space and contributes to outlet impingement syndrome. This may be prevented by strengthening the rhomboids and scapular retractor muscles.

Take-home message

The only intervention that has been proven effective in preventing traumatic shoulder injury is the introduction of break-away bases in softball. Theoretical preventative measures like shoulder pads, collars, learning falling techniques, forbidding risky playing habits, and softening walls, and back stops have yet to be proven effective.

The risk for overload injuries, which are very common in shoulders, can theoretically be reduced if all athletes are screened regularly for weakness in glenohumeral and scapulothoracic stability and for lack of balance between muscles (identifying dominance of muscles, most often inward rotators of the arm and downward rotators of the acromion). It is recommended that weaknesses and dysfunctions are treated by exercise programs, but the effect of this on injury prevention remains to be proven. Learning the proper techniques in the individual sports is thought to be important for prevention of overload.

The growing athlete is at particular risk for overload injury, for example, at the growth plates, and repeated, forceful activities should be reduced, for example, the number of pitches per game.

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Chapter 10

Preventing elbow injuries

Mark R. Hutchinson[1] and James R. Andrews[2]

[1]Department of Orthopaedics, University of Illinois at Chicago, IL, USA
[2]Medical director, American Sports Medicine Institute, Birmingham, Alabama, USA, Andrews Sports, Medicine Institute, Gulf Breeze, FL, USA

Epidemiology of elbow injuries in sports

The elbow is a complex hinge joint that joins the distal humerus to the proximal radius and ulna. The joint has two degrees of freedom, flexion/extension and pronation/supination, which play important roles in most sports by transferring forces between the body core and shoulder to the hand. In addition, the elbow allows the athlete to specifically, repetitively, and with a great deal of finesse position their hand in space. Excessive forces leading to injury can come from acute loads as seen in direct trauma and falls or chronic loads as seen in overuse and repetitive microtrauma.

High demand versus low demand sports

Sports with relatively low upper extremity demand would be expected to have low risk of elbow injuries; and, indeed, this is true. Soccer (other than the goalie), track and cross-country, as well as the purely jumping sports such as long jump, high jump, and triple jump have a low risk of elbow injuries. Other sports such as Nordic or Alpine skiing, equestrian, cycling, speed skating, and figure skating have relatively low risk until high energy falls are considered. When all sports are considered in adolescent athletes, the elbow accounts for only 2–5% of all injuries (Table 10.1). In sports that have a higher throwing demand such as baseball the incidence jumps up to 17–70% depending on the position, age, and definition of injury (Table 10.1).

High energy injuries

The transfer of large, acute loads risks catastrophic failure of ligaments, tendons, or bone. The most common acute traumatic mechanism is a fall on an outstretched hand. Acute traumatic injuries are most common in contact and collision sports (American football, rugby, martial arts, etc.), sports that place an athlete at elevated heights (high jump, ski jumping, gymnastics, etc.), and high energy sports in which the athlete is at a great rate of speed (alpine skiing, speed skating, cycling, etc.). Eight percent of judo injuries, 4% in wrestling, and 3–4% in ice hockey involve the elbow (Table 10.1). In addition, sports such as weight-lifting, boxing, shot put, and gymnastics place acute and heavy loads across the elbow joint during the course of participation. In some cases, the force across the elbow can far exceed the body weight of the gymnast, the weight being lifted, or the weight being thrown. If the loads aren't balanced appropriately across the joint, catastrophic failure occurs. The differential diagnosis of traumatic injury of the elbow includes: elbow dislocation, radial head dislocation; intra- and extra-articular distal humerus

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Table 10.1 Risk of elbow injury in different sports. The numbers reported are average estimates based on the studies available.

Sport	Competition incidence[1]	Training incidence[1]	% of all injuries Rank	Comments
Team sports				
Baseball	0.29*		8.60%	
Softball	0.17*		4.70%	
Ice Hockey	0.14*		2.8–4.6%	
Basketball (♀)	0.06*		1.20%	
Basketball (♂)	0.06*		1.10%	
Football (American)	0.08*		1%	
Lacrosse (♂)	0.04*		0.70%	
Lacrosse (♀)	0.03*		0.60%	
Volleyball (♀)	0.01*		<0.5–1.6%	
Beach volleyball	0.01		<1% (14th out of 17)	Competition 3× more common than training
Soccer (♂)	0.01*		<0.5–1.3%	
Soccer (♀)	0.01*		<0.5%	
Field hockey	0.01*		<0.5%	
Waterpolo	0.02		<1%	
Individual sports				
Sailing	0.04		13% (3rd most common)	
Javelin	0.11	0.03	1.4–6%	High risk of DJD at long term follow up
Tennis				
– Club level	2.4		35%	
– Elite <18 year	1.2		5%	
Golf				
– professional	0.06–0.12		5% ♀/7% ♂ (2nd most common)	Overuse most common
– amateur	3× more common than pros		35.5% ♀/32.5% ♂	
Judo	1.2		7.70%	
Wrestling	0.39*		4.30%	
Gymnastics (♀)	0.38*		4.10%	
Gymnastics (♂)	0.10*		1.90%	
Karate	0.10		3.80%	
Weight-lifting (Olympic)			2.50%	
Boxing	0.5*		1.00%	↑ DJD when retired
Mixed martial arts	0.06*		2.10%	
Paralympic sport				
– Wheelchair sports	1.5		12%	30–60% related to training
– Sled hockey	1		5%	
Luge	0.39		6–13%	

[1] Incidence is reported for adult, competitive athletes as the number of injuries per 1000 hours of training and competition or *per 1000 athletic exposures.

fracture; physeal injury in the skeletally immature, radial head or neck fracture; avulsion injury of the epicondyle, olecranon, or coronoid; distal biceps tendon rupture; triceps rupture; nerve contusions; ulnar nerve subluxation; or neurovascular injury. In some instances, the rules of participation may reduce the risk of catastrophic injuries; nonetheless, traumatic injuries are the most difficult to target with prevention. They also have the greatest risk of leaving residual deformity, loss of function or restrictions in motion, or arthritis, which can lead to permanent disability.

Low energy/overuse injuries

Repetitive subcatastrophic load may cause chronic overuse or repetitive microtraumatic injury such as tendinopathy, stress fracture, and ligament sprain. Chronic overuse can weaken the native structural elements to the extent that normally submaximal loads exceed the ultimate strength of the structure and lead to catastrophic failure. Repetitive overuse injuries are more common in upper extremity demanding sports that use a racquet or stick (tennis, racquetball, golf, lacrosse, etc.) or throw an object (javelin, baseball, softball, etc.). Nearly 9% of baseball injuries, 7% of javelin injuries, 5% of softball injuries, and 3% of tennis injuries involve the elbow (Table 10.1). It is in these sports that the elbow's functional demand of repetitively placing the hand in space is particularly important. With subtle variations of hand positions the ball or object to be delivered may end up in a completely unintended location. Failure or dysfunction at the elbow will lead to poor performance and potentially further injury at the elbow or adjacent structures. Chronic overuse injuries about the elbow include: tendinopathy of the extensor carpi radialis brevis (tennis elbow), tendinopathy of the flexor muscle insertions (golfer's elbow), bicipital tendinopathy, cubital tunnel syndrome (ulnar neuritis), ulnar nerve instability, pronator teres syndrome (median nerve entrapment), stress fractures, osteochondritis dissecans, or valgus extension overload syndrome with associated spurring or loose body formation from the olecranon or capitellum. Overuse injuries are more common than acute traumatic injuries, and are easier to target regarding injury prevention. In one study of 21 javelin throwers 19 years after sports participation, all had degenerative changes in their elbow and 50% had loss of extension.

Key risk factors: how to identify athletes at risk

When making an effort to prevent injuries, it is important to recognize not only the overall risk in a specific sport but also any key risk factors relative to the athlete. Is it possible to identify athletes at risk to be able to target prevention programs? These factors may be categorized as either internal or external influences. Internal factors include the unique anatomy of the elbow, age of the participant relative to physeal closure, articular alignment, physical strength, and coordination of the kinetic chain (Table 10.2). Gender may play a small role; however, it is more likely that how intensely and how often the athlete uses his elbow is the greatest risk factor. External factors include such things as the level of play, number or repetitions or throws, amount of rest between competitions, risk of contact and collision in a specific sport, equipment, environment, and the technical style (form, overhead motion versus side-arm motion, or coordinated progression of the kinetic chain).

Young athletes and growing bones

The skeletally immature elbow has numerous ossification centers and growth plates which, regarding injuries, are the "weak link." The ossification center of the capitellum is at risk of vascular injury secondary to repeated compression associated with weight-lifting and boxing, the weight-bearing demands of gymnastics, or the valgus stresses associated with throwing (Figure 10.1). On the medial aspect of the skeletally immature elbow, the medial epicondylar ossification center serves as the insertion of the medial collateral ligament and flexor muscles of the forearm. It is at risk of avulsion secondary to the tension forces when the elbow perceives valgus loads such as in weight-bearing, weight-lifting, or throwing. Isolated ulnar collateral ligament injuries are uncommon in the skeletally immature thrower; however, a growing field of literature has reported this injury as well as surgical reconstruction in this population.

Mature and masters athletes

For the skeletally mature athlete, chronic changes can occur on the lateral side of the elbow including the creation of bone spurs, radial head hypertrophy, flattening and fragmentation of the capitellum which in turn leads to loose bodies. On the medial side of the mature elbow, the ulnar collateral

Table 10.2 Internal and external factors for elbow injuries in different sports. The numbers reported are average estimates based on the studies available.

Risk factor	Relative risk[1]	Evidence[2]	Comments
Internal Risk Factors			
Prior injury	2×	++	
Prior osteochondrosis	2×	+	Increased risk of OCD of the elbow in athletes with prior osteochondrosis
Alignment			
– Elbow carrying angle	1×	+	
– Developmental glenohumeral external rotation deficit (GERD)	?	+	Unknown correlation with elbow injuries
Skeletally immature	2×	++	
Gender (male vs female)	1×	+	Males > Female likely related to # of participants & sport demands, not gender
External Risk Factors			
Court surface	1×	+	No effect on elbow injury rates
Number of throws	3×	++	
Number of years of throwing	2×	+	Cumulative effect ↑risk over time
Throwing style	1×	+	Overhand vs sidearm styles
– Softball	0.5×	+	Windmill style reduces elbow risk
Backhand style in tennis	0.5×	++	Two fisted ↓elbow injury risk
Type of pitch	X	+	Little effect but poorly thrown curveball,
– Fast ball vs curveball			↑ risk of injury in the youth
Elbow pads	0.5×	+	
Tightly strung racquets	2×	+	
Oversized racquet heads	0.5×	+	
Oversized grips	0.5×	+	Some debate. Probably reduces the tension over the
	2×	+	extensor muscle mass which reduces the risk of tennis elbow
Wet or heavy balls			

[1]Relative risk indicates the increased risk of injury to an individual with this risk factor relative to an individual who does not have this characteristic. In this chart, standard risk would be 1×. The magnification estimates are based on considering a mild increased risk to be 2× and a moderate to significant increased risk to be 3×. A mild estimate of reduction of risk would be 0.5× and a moderate to significant risk reduction to be 0.25×.
[2]Evidence indicates the level of scientific evidence for this factor being a risk factor for ligament sprains: ++ — convincing evidence from high-quality studies with consistent results; + — evidence from lesser quality studies or mixed results; 0 — expert opinion or hypothesis without scientific evidence.
* Odds ratio and not relative risk.
NA: Not available.

ligament and not the medial epicondyle is the weak link. Weight bearing on the upper extremity or the throwing motion places a tension load across the ulnar collateral ligament which can lead to injury or failure (Figure 10.2). Masters athletes (older athletes) have placed a life-time of wear and tear on their joints and are at greater risk of degenerative and overuse problems than the young athlete. The elevated risk of tennis elbow (extensor carpi radialis tendinopathy) in the master's athlete compared to the younger athlete is well recognized. Chronic degenerative changes including joint space narrowing and peri-articular spurring are more commonly seen in older throwers, gymnasts, weight-lifters, and martial artists.

Injury risk builds from the ground up

Recent focus on elbow injury prevention has looked beyond specific anatomic structures of the elbow and targeted the efficient transfer of forces from the ground through the body core and shoulder to the elbow in throwing athletes; that is, the kinetic chain (Figure 10.3). The health

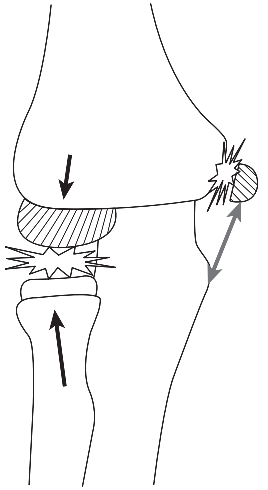


Figure 10.1. Valgus load on the skeletally immature elbow risk compression of the capitellum and development of osteochondritis dissecans (solid black arrows) and/or traction of the medial epicondyle apophysis with possible avulsion (solid grey arrows)

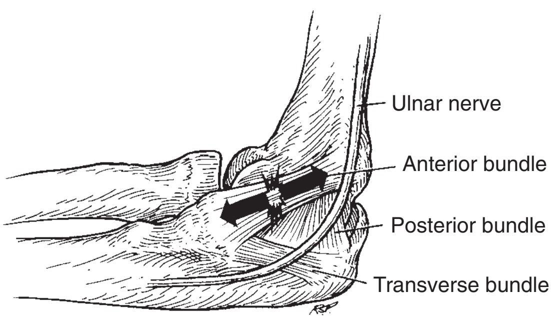


Figure 10.2. Anatomic drawing of the medial elbow ligaments. Anterior bundle is loaded during the throwing motion and is at risk of failure due to tension loads. Reproduced with permission @ Mary Lloyd Ireland M.D., Kentucky Sports Medicine

of the elbow is dependent on coordinated movement, transfer of forces, and health proximally in the kinetic chain. This is particularly true in the throwing athlete where poor coordination of the scapular stabilization muscles (scapular dyskinesia) has been directly correlated with an increased risk of elbow injuries. Similarly poor coordination of core muscles including the lumbar spine, abdominals, and gluteal muscles has been associated with poor transfer of kinetic forces and overuse of the structures about the elbow. The throwing athlete with poor core mechanics tends to alter their throwing style in an effort to maintain the same throwing velocity. This is often at the expense of ideal shoulder and elbow positioning which places the elbow at an increased risk of injury. A history of shoulder injuries, indeed a history of any injury along the kinetic chain, has been directly correlated to an increased risk of elbow injuries (Table 10.2).

Identifying external risk factors

In addition, a number of external factors play key roles in the incidence of elbow injuries. These external influences include how frequently the athlete is asked to use or load the elbow, how much rest is allowed between events to allow the elbow to recover, certain styles of performance, as well as the effect of equipment modifications including grips, braces, string tension of racquets, and weight or size of a projectile being thrown (Table 10.2). Baseball, a classic throwing sport, and tennis, a classic racquet sport, have been the two sports subjected to the greatest scientific scrutiny.

In baseball, a ball is delivered in an overhand throwing style at speeds approaching 160 km/h over 100 times in a game. As the athlete fatigues, he may develop a poor throwing style that does not take advantage of an efficient kinetic chain and leads to an increased risk of overuse and injury. Excellent studies are available in the skeletally immature thrower that show that elbow injuries including medial epicondyle epiphysitis and osteochondritis dissecans are directly associated with the total number of pitches delivered per game, per week, and per season (Table 10.2). The same studies reveal that limiting young throwers to a certain number of pitches can reduce the overall incidence of injury. In addition, when the young athlete is allowed a period of rest between outings, his elbow is allowed to recover and the incidence of injury is further reduced.

Throwing mechanics including specific pitch type have also been carefully studied in baseball regarding their relationship to injury risk (Figure 10.4). Fast balls and change-ups are thrown with

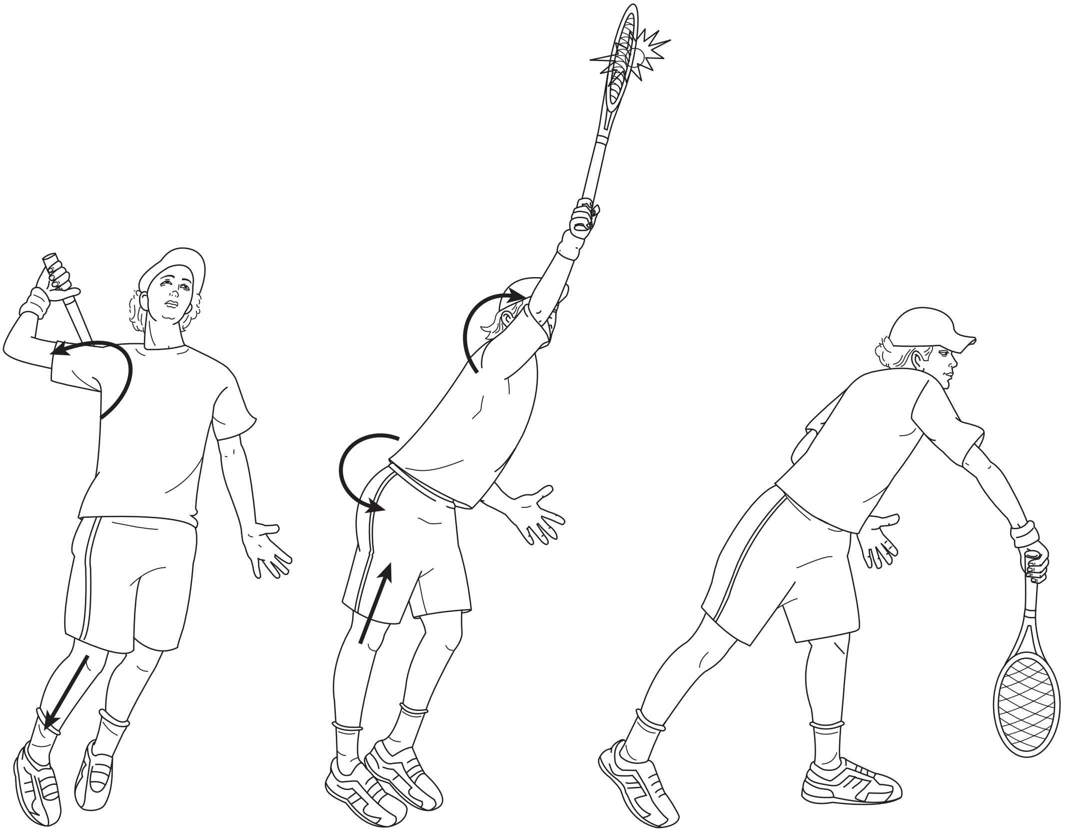


Figure 10.3. Optimal throwing or serving technique requires a sequential force transfer from the floor up the leg, thru the torso and shoulder to the elbow and hand at delivery; that is, the kinetic chain

the most natural of mechanics and are the pitches by which all others are compared. The fast ball has been shown to create the greatest forces across the elbow joint followed by the slider, curveball, and change-up. A curveball is thrown by altering the pitcher's grip on the seams and by repositioning their wrist during the delivery. In a well-thrown curveball, very little mechanical change is perceived across the elbow. However, in a young thrower learning to throw the pitch, they tend to drop their hand delivering the ball in a more side-arm motion, they tend to lead with their elbow throwing the ball more like a dart. Alternatively, the young thrower may try to explosively supinate their forearm with delivery. These mechanical alterations increase the load across the elbow and increase the risk of injury. For this reason, throwing the curveball is discouraged in the skeletally immature thrower until nearing skeletal maturity when they can perform it with proper technique and do not risk their open growth plates.

In elite level pitchers the side-arm motion has been studied and shown to have very little correlation with elbow injuries. In a well-thrown side-arm pitch, the angles and forces across the

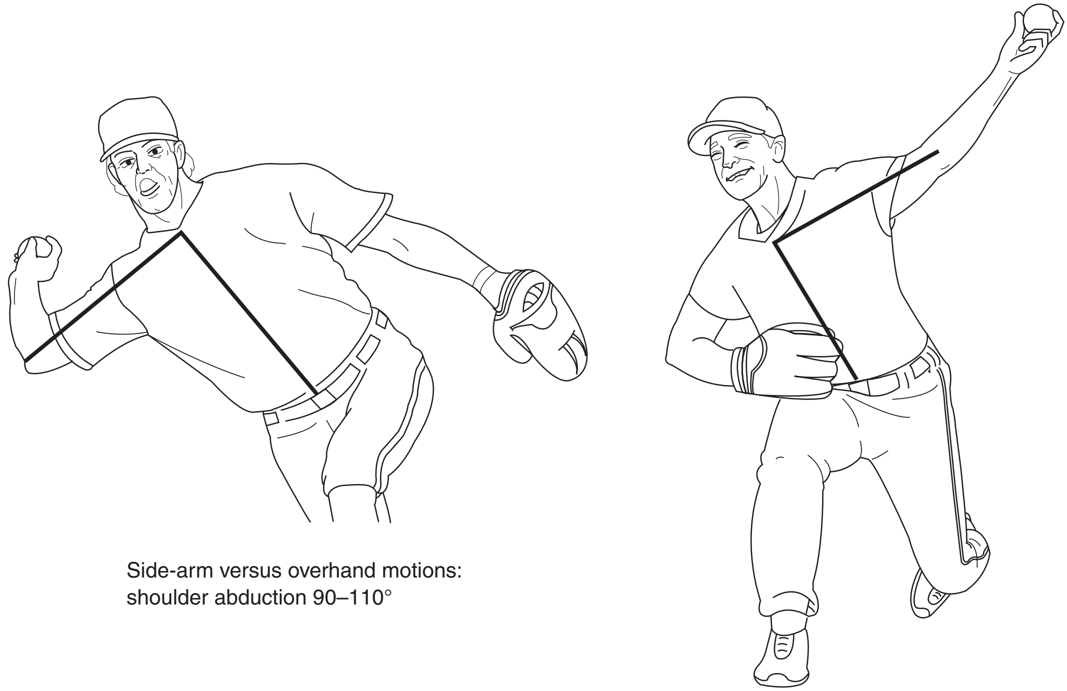


Figure 10.4. The side-arm motion of delivery is actually just a lateral bend at the torso and not less shoulder adduction

shoulder and elbow are nearly identical to the overhead motion. The difference occurs in the lateral tilt of the torso in the side-arm thrower. While this may increase the risk of low back problems, there does not appear to be increased loads across the elbow (Table 10.2, Figure 10.4). Windmill style of pitching seen in softball has very little risk of elbow injury.

Risk factors in racquet sports

During service, tennis and many racquet sports mimic the overhead throwing motion. Therefore, athletes in racquet sports can be equally susceptible to repetitive overuse injuries and failures in the kinetic chain as are athletes participating in predominantly throwing sports. The racquet provides an increased extension moment that can further load all units of the kinetic chain including the elbow (Figure 10.5). Longer racquets increase the load. Tighter strung racquets or more rigid racquets absorb less shock and transfer the loads directly up the kinetic chain with the first stop being the wrist and elbow. It is, therefore, not surprising that longer, rigid racquets with tight strings increase the risk of tennis elbow in the athletes that use them (Table 10.2). Increased forces are also seen when players play with wet or heavy tennis balls. Large headed racquets increase the size of the "sweet spot" which reduces the chance of a miss hit that might cause rotational torque in the forearm. Theoretically this will reduce the risk of injury. Grip size has also been associated with injury risk and particularly increased risk of tennis elbow. A small grip forces the athlete to shorten their flexors and places the finger and wrist extensors at greater length. This increases the forces at the elbow during a backhand or wrist extension maneuver. Larger grips have been used to reduce this risk or treat the athlete with an early onset of lateral tendinopathy. Recent studies have suggested that grip size changes of less than ¼ of an inch have no effect on forearm muscle firing patterns. Reduction of the forces along the elbow extensors has also been targeted through biomechanical adjustments in technical style. Two-fisted

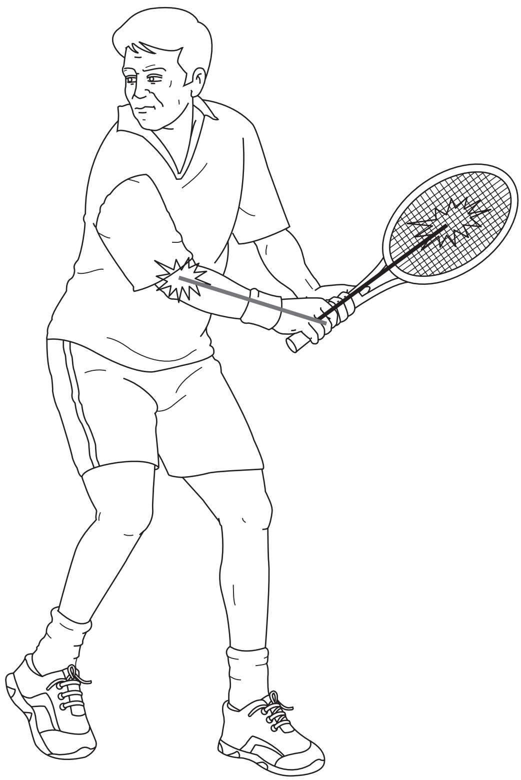


Figure 10.5. The racquet increases the distance of the impact of the ball from the elbow. This increased moment magnifies the forces felt at the elbow

back-hands have been shown to reduce the forces across the lateral elbow when compared to single-fisted backhands.

The training location and court surface may play a minimal role. Court surface in tennis, clay versus grass versus synthetic, does alter ball speeds but has not been directly related to elbow injuries. Likewise ball players on grass versus synthetic turf have not been correlated with an increased risk of elbow injuries although falls on synthetic turf lead to more skin abrasions than on natural grass.

Sports with compressive loads across the elbow

Repetitive compressive loads across the elbow such as seen in weight-lifting, boxing, and gymnastics are another key risk factor for the development of chronic elbow problems. In the skeletally immature elbow these repetitive compressive loads have been directly associated with osteochondritis dissecans of the capitellum, olecranon impingement, and medial epicondylitis (Figure 10.1). The intensity and frequency of loading may place the skeletally mature elbow at risk of degenerative changes of the articular surface or the creation of osteochondral loose bodies. Many master athletes who have participated for many years develop secondary changes and degenerative changes in the lateral and posterior compartments of the elbow. Identifying the athlete at risk of elbow injuries from compressive loading begins with early recognition of complaints and an immediate period of rest. Loading and weight-bearing are inherent to the sports of boxing, gymnastics, and weight-lifting and cannot be eliminated completely.

Take-home message

So which athlete should you keep the closest eye on and plan an early intervention? Surprisingly, the answer is usually the best athlete. He/she is the one who has the most repetitions, creates the highest forces across the elbow, and is likely to be the most intense in training taking minimal periods of rest. Be attentive to faulty mechanics in not only sport-specific techniques but also of core strength and stability. Young athletes should be progressive in their skill-building. If performance begins to decline, it may be the first sign in the development of an overuse injury which should indicate initiating a period of rest and recovery.

Injury mechanisms

As noted earlier, elbow injuries can be classified as acute or chronic. Acute injuries are more common in contact and collision sports (American football, rugby, ice hockey, and martial arts) or in any sport at risk of high energy falls (skiing, snowboarding, gymnastics, and equestrian). There may be direct (impact directly onto the elbow) or indirect (fall on an outstretched hand or torques across

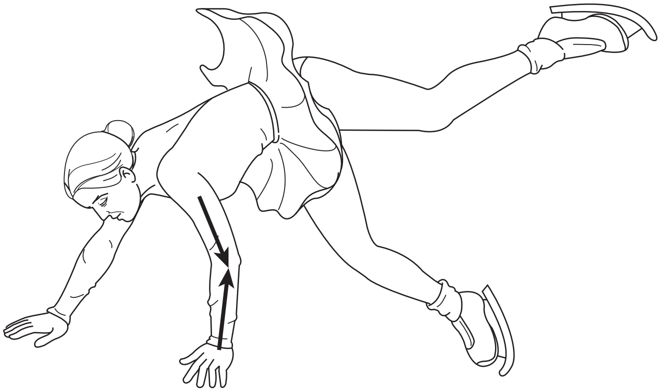


Figure 10.6. Fall on an outstretched hand (FOOSH) is a common cause of elbow injury and dislocation

the elbow. Most acute injuries are hazards of the sport and therefore difficult to prevent. Educating athletes on how to fall and the use of protective equipment like elbow pads in certain sports may provide some prevention effect.

FOOSH: fall on an outstretched hand

The classic description is a fall on an outstretched hand (FOOSH) (Figure 10.6). When the forces are excessive, the elbow is hyper-extended leading first to rupture of the collateral ligaments (medial before lateral) and anterior capsule. If the force continues, the elbow will dislocate. In some cases, bony avulsions of ligaments or apophyses will occur instead of pure ligamentous injury. In severe injuries, neurovascular structures will be injured with severe displacement. Urgent reduction is essential. In athletes who fall on extended elbow with the hand in full supination, there is a risk of an isolated injury to the posterolateral corner of the elbow. In this case, the lateral collateral ligament and annular ligament at the radial neck are injured and lead to posterior subluxation or instability of the radial head.

In children who fall on an outstretched arm, the weak link is the growth plate. Injuries that appear as elbow dislocations frequently have associated epiphyseal or apophyseal injuries. It is strongly recommended to obtain bilateral radiographs in the skeletally immature for comparison. The appearance and position of each growth center should be symmetric to the opposite side. Anatomic reduction of any displaced intra-articular fracture or a supracondylar fracture is essential to avoid long-term complications of malalignment or arthritis. Admittedly, this does not prevent the initial injury but early recognition and treatment can prevent later problems and disability.

Direct impact injuries

Direct impact onto the elbow by an object, impact onto the court surface, or collision into a barrier wall can lead to elbow injuries including bone bruises, ligament strains, muscle contusions, and skin abrasions. The ulnar nerve is relatively subcutaneous on the posterior medial aspect of the elbow. Direct impact can lead to a temporary neuropraxia or chronic ulnar neuritis. Direct impact onto the olecranon can lead to an inflamed or blood-filled olecranon bursa. Prevention of these direct impact injuries can usually be accomplished through protective padding. Unfortunately, many acute injuries are simply accidents which occur during the usual performance of a high risk sport. One potential exception is the risk of elbow dislocation in the sport of judo. In judo, a competitor is allowed to place his opponent's elbow in an elbow lock, a position of hyperextension. Indeed, if the athlete on the receiving end of this maneuver does not "tap-out" to concede defeat continued force may lead to an elbow dislocation.

Overuse injuries

While traumatic injuries can occur across sports, the most elbow problems in athletes are secondary to chronic repetitive stresses. Fortunately, it is this overuse that gives us our best target to prevent elbow injuries. Repetitive varus loading as seen in the lead hand in golf and in the backhand during tennis leads to strain of the lateral collateral ligament as well as the wrist extensor muscles. Repetitive valgus stress seen in throwing and racquet sports leads to an increased strain of the medial collateral ligament, overuse of the flexor muscles, and compression of the radiocapitellar articulation (Figure 10.7). Repetitive extension loads seen in the follow-through phase of throwers or when weightlifters lock their elbow in full extension can lead to impingement of the olecranon posteriorly, traction of the triceps muscle, and tension the capsule anteriorly. Repetitive compressive loads seen in gymnastics and weight-lifting serve to load the articular surface directly. In each case the ligaments and bones feel the direct force of the loading, however, the muscles that cross the joint serve as dynamic stabilizers that are at risk of injury with repetitive overuse.

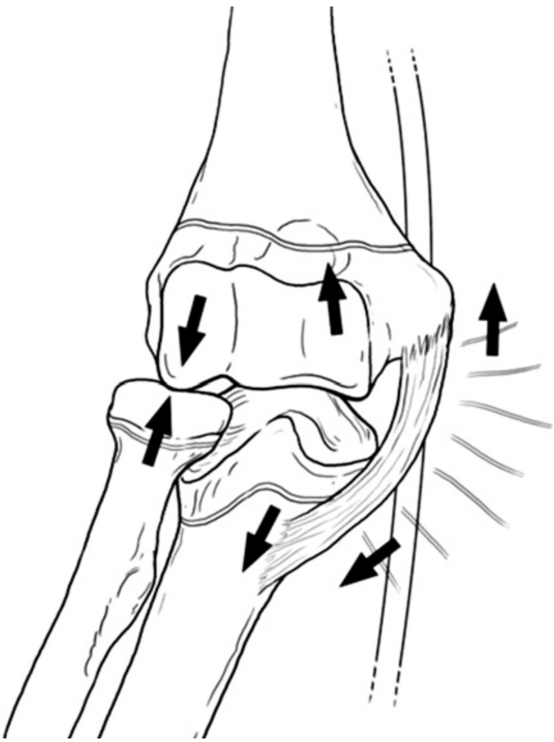


Figure 10.7. Valgus-extension overload is the most common mechanism of overuse injuries about the throwing elbow. It is made up of medial tension, lateral compression and posterior olecranon impingement. Reproduced with permission @ Mark R. Hutchinson, UIC Sports Medicine

To resist varus loading, the lateral muscles fire to assist in stabilizing the joint. Unfortunately due to the relative proximity to the joint surface they are at a mechanical disadvantage to overcome these repetitive loads. The classic example of this occurs with the tennis backhand. Energy is transferred at ball impact through the racquet to the wrist extensors which insert on the lateral aspect of the elbow. Chronic repetitive overuse with inadequate opportunity to recover leads to tendon failure or tendinopathy of the wrist extensors, most commonly the extensor carpi radialis brevis. Indeed a similar phenomenon is seen on the medial aspect of the elbow in golfers (Figure 10.8). As ball impact occurs or a divot is taken, forces are transferred up the shaft to the wrist flexors as the insert on the medial aspect of the elbow. Golfer's elbow is a tendinopathy on the medial aspect of the elbow secondary to overuse or injury the flexor muscle insertions onto the medial epicondyle. It is possible that the strong supination of the lead hand/pronation of the trailing hand that occurs during the golf swing could

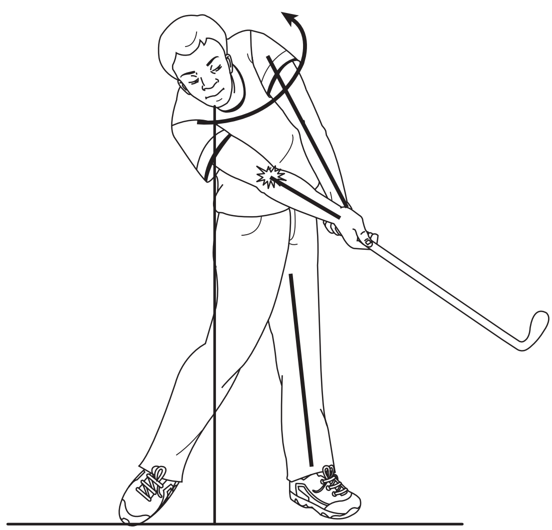


Figure 10.8. Golfer's elbow is an overload of the medial structures of the elbow which can be caused by acutely taking a deep divot

contribute to this problem; however, this would not explain the increased incidence in the amateur population compared to the professional ranks. The more likely mechanism of injury is that the injury occurs when the golfer hits down on the ball too forcefully and takes too large a divot. This would lead to acute loads of the flexor muscles of the trailing hand at impact. Indeed this occurs much more frequently in amateur golfers than professional golfers who have honed their swing.

Injuries in throwing sports

Perhaps the greatest focus of study on injury mechanisms about the elbow has occurred in throwing sports. As the ball or javelin is delivered, the elbow goes through a sequence of muscle activity, loading, and mobility that stresses different aspects of the joint through the range of motion. In the early cocking phase, the elbow is usually in slight to moderate flexion and is relatively at a low stressful position as the arm is being positioned to begin transferring loads up the kinetic chain with the goal of ultimately delivering the projectile from the hand. In late cocking and early acceleration the medial collateral ligament and radiocapitellar articulation are loaded with valgus stress that continues to increase as acceleration occurs (Figure 10.9). Throwers usually pronate their arms to some degree in this phase to reduce the intense valgus loads. As the projectile is delivered, the elbow comes into full extension and the perarticular muscles (especially elbow flexors) fire to resist the large extension moment. The extension moment is also resisted by the bony architecture posteriorly as the olecronon falls into the olecranon fossa posteriorly. This repetitive valgus loading and extension moment can lead to specific group overuse injuries and, therefore, this pathomechanic has been coined valgus-extension overload. The valgus component can lead to ulnar collateral instability, avulsions of medial epicondyle, medial epicondyle epiphysitis, secondary ulnar nerve neuropraxia. In addition the valgus loads apply compressive loads to the radio-capitellar articulation which can lead to radial head fractures, radial head hypertrophy, osteochondral lesions, degeneration of the capitellum, or osteochondritis dissecans. The extension component leads to posterior olecranon impingement. In association with valgus instability, this extension component leads to specific spurs on the posterior medial aspect of the olecranon that engage during the throwing motion and can lead to pain or create loose bodies. This valgus extension overload mechanism is exactly the same during the overhead service in racquet sports.

Another common mechanism of chronic elbow injury is the repetitive compressive loading as seen in sports such as gymnastics, boxing, and weightlifting. The anatomic structures at risk are the same as those with throwing athletes; however, the compressive loads are greater. This places the articular surface at a relatively greater risk of overuse failure compared to throwers with similar number of loads events. This may explain why gymnasts

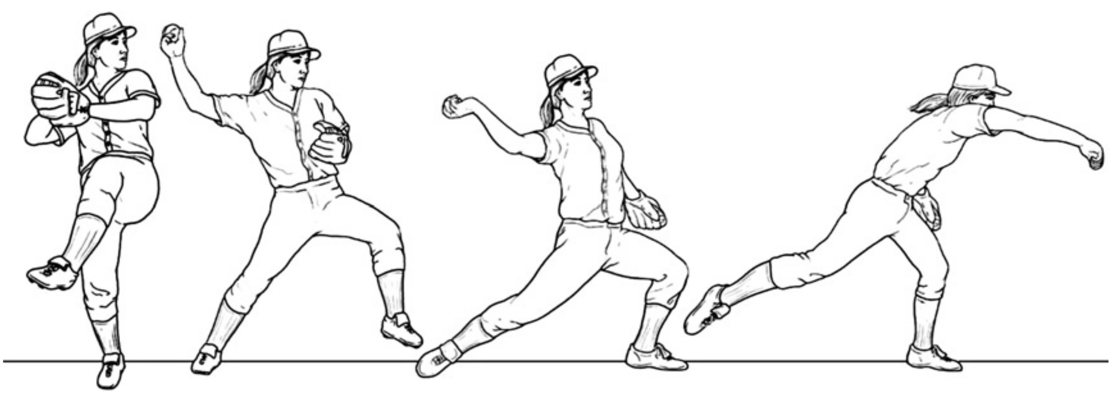


Figure 10.9. The normal throwing sequence consists of wind-up, cocking, acceleration, and follow-thru phases. With approval @ Mark R. Hutchinson, UIC Sports Medicine

who suffer osteochondritis dissecans have a miserable prognosis regarding return to sport compared to their young baseball counterparts who seem to have a better prognosis.

Identifying risks in the training and competition program

As we have seen, multiple factors contribute to the incidence and prevalence of elbow injuries in athletes. The relationship of training, practice, or competition to injury incidence has been well studied regarding injuries in general but less well evaluated for elbows in particular. The key issues for elbow injuries are the number of repetitions or exposure to traumatic events in training versus competitive situations. In contact and collisions sports, the athlete is at greater risk of acute trauma during competition where their opponent is trying to overwhelm their strength or position. In practice situations, players more frequently are less "all out" as compared to a competition. An exception to this rule is spring football in American rules football in which teams play competitively amongst their own team vying for positions on the next years teams. Injury rates are greater at this time than the regular season. For gymnasts, they are at risk of traumatic injuries at any time they are at competition height on apparatus regardless practice or competition.

Training versus competition seems to have a major effect on overuse injuries. Overuse injuries are always more common when an athlete begins to train intensely after an extended period of rest or when they are asked to significantly ramp up their training immediately prior to a major competition or event. This is true for the elbow as it is for most body parts. Prevention usually targets a gradual increase in stresses and intensity rather than these acute changes in training patterns to avoid the risk of overuse injuries.

Skeletal maturity and training

For the skeletally immature thrower, the injury risk appears to be less related to training or competition compared to the actual number of full speed tosses they perform in a given time period. Too many throws on too little rest is directly related to an increased injury incidence. Likewise for the mature thrower, overuse elbow injuries have been related to the total number of pitches and amount of rest between outings.

For the mature athlete, core strength and a coordinated kinetic chain have a central role in injury prevention. Coaches and trainers should carefully evaluate the throwing mechanic of their athletes early in the training season to assure that there are no deficits in the kinetic chain that might predict future injury. During competition, the kinetic chain may also play a key role in the risk of elbow injury. As the athlete fatigues later in competition, he is more likely to overuse single components of the kinetic chain leading to a failure of the coordinated sequence of movement and placing any link at risk of injury. Based on this knowledge, coaches should be astute observers of athletic performance and biomechanics during competition. The athlete should be removed from play when proximal links of the kinetic chain reveal weakness, poor coordination, or failure because the elbow may be the next link to fail.

Preventive measures

The foundation of a targeted prevention plan to reduce elbow injuries should be based on available science and our historical knowledge regarding incidence and mechanism. The ideal of eliminating all injuries is not reasonable as athletic participation carries some inherent risk. Nonetheless, minimizing risk and preventing the progression of a minor deficit or problem to a more significant injury is clearly our best option. A valid prevention plan should target the injury patterns that are most common, most potentially disabling, and in which intervention can be the most effective.

Targeting acute injuries

For acute and traumatic injuries of the elbow, prevention should target minimizing risk exposures and energy level when such an exposure would not affect the routine and legal performance of

Table 10.3 Injury prevention matrix for elbow injuries: potential measures to prevent injuries.

	Precrash	Crash	Postcrash
Athlete	Hand dominance Throwing technique Backhand technique in tennis Core strength and stability Optimal shoulder function Pitch counts	Falling techniques	Comparative radiographs in children to avoid missing complex injuries Regain motion ASAP to avoid contractures
Rules	Restrictions of repetitions in underage throwers Regulations versus at risk techniques in martial arts		
Material	String tension in racquet sports Racquet rigidity Length of racquets Decrease weight of projectiles	Elbow pads in collision sports	Therapeutic taping to avoid recurrent hyperextension Pads to avoid recurrent bursitis
Environment	Rainy weather increases ball weight	Padded surfaces absorb fall energy	First aid readily available Only qualified professional to perform reduction of dislocation

the sport. This may be accomplished via rigid rule enforcement, more severe penalties for violations, or rules changes. An example that has been effective was limiting the height of cheerleader towers which, in turn, reduced the potential energy and risk of injury from falls (Boden et al., 2003). Examples that could be effective include rules changes, the imposition of stiffer penalties or the rigid enforcement of existing rules that prevents a wrestler from lifting his opponent off the matt or tossing his opponent through the air. In judo, banning the ability of a competitor to hyperextend the elbow (or dislocate it) until his opponent taps out (gives up) would likely reduce the risk of elbow injuries in that sport.

Targeting the environment

Targeting issues of athlete fatigue as well as ensuring safe equipment and environment would also reduce the risk of elbow problems. Athletes should be instructed to rest when fatigued. This is especially true when their partner is dependent on their elbow's strength and function (pairs figure skating, cheerleading) or when they are participating in a high energy sport such as gymnastics in which a fall could be catastrophic. Equipment and apparatus should be checked for proper function before competition begins. If competition apparatus is unstable or set at the wrong height, it may predispose the athlete to a fall. There is good literature to support that the use of elbow pads in rollerbladers reduces their risk of elbow injuries especially of contusions and abrasions (Schieber et al., 1996; Jerosch et al., 1998; Sheiker & Casell, 1999). Elbow injuries in rollerbladers are most strongly correlated with their willingness to perform advanced tricks and maneuvers. The use of elbow protection in sports at risk of direct contusion such as hockey, lacrosse, or racquetball may reduce the risk of these contact injuries. In addition better designs and fitting with improved shock absorption may assist to a diffuse the load of the more significant direct injuries (Table 10.3).

Targeting overuse

While avoiding a single catastrophic injury, particularly for the individual athlete, is important, the most effective aim for elbow injury prevention should target the most common injuries; that is, overuse injuries. The foundational knowledge of injury risk, risk factors, and mechanisms should serve as our guide to developing an injury prevention plan for the elbow that can be applied to all sports but also one that can be individualized to create a sport-specific plan. Athlete's at risk of elbow injuries due to a history of previous elbow injuries or due to their participation in at risk sports golf, baseball, softball, javelin, tennis, and wrestling should be more thoroughly evaluated on preparticipation physical examinations. The presence of elbow stiffness or pain should be addressed with appropriate therapy prior to release for unrestricted training. Extension loss of greater than 15° at the elbow or an abnormal carrying angle secondary to development or previous injury will likely lead to abnormal mechanics and future overuse injury. For all overhead and upper extremity dominant athletes, the screening program should also include a thorough assessment of shoulder function and motion. Posterior capsular tightness evidenced by a loss of internal rotation has been directly associated with both shoulder and elbow complaints. Fortunately in a large majority of cases, the shoulder tightness responds to a focused program of capsular stretches including cross-over stretches, internal rotation stretches, and "sleeper" stretches. The latter are performed as the athlete lays on his side trapping the effected scapula between his body and the bed followed by internal rotation stretches in various positions.

Table 10.4 Interval throwing program: baseball. All throws should be on an arc with a crow hop. Warm-up throws should be 10–20 tosses at 30 ft. Perform each step 2–3 times before progressing. If pain occurs go to previously level. Distances should be shortened for Little Leaguers.

Step	Throwing program
Step 1 & 2: 45-ft Phase	
	1. Warm-up, 25 tosses, 5-min rest, repeat
	2. Warm-up, 25 tosses, 5-min rest, repeat twice
Step 3 & 4: 60-ft Phase	
	3. Warm-up, 25 tosses, 5-min rest, repeat
	4. Warm-up, 25 tosses, 5-min rest, repeat twice
Step 5 & 6: 90-ft Phase	
	5. Warm-up, 25 tosses, 5-min rest, repeat
	6. Warm-up, 25 tosses, 5-min rest, repeat twice
Step 7 & 8: 120-ft Phase	
	7. Warm-up, 25 tosses, 5-min rest, repeat
	8. Warm-up, 25 tosses, 5-min rest, repeat twice
Step 9 & 10: 150-ft Phase	
	9. Warm-up, 25 tosses, 5-min rest, repeat
	10. Warm-up, 25 tosses, 5-min rest, repeat twice
Step 11 & 12: 180-ft Phase	
	11. Warm-up, 25 tosses, 5-min rest, repeat
	12. Warm-up, 25 tosses, 5-min rest, repeat twice
Step 13 & 14: progression to pitching: flat ground stage	
	13. Warm-up, 60-ft/15 tosses, 90-ft/10 tosses, 120-ft/10 tosses, 60-ft/20 tosses using pitching mechanics from flat ground
	14. Step 13, 10-min rest, repeat
Step 15: pitching: mound stage	
	15. Progression to pitching from mound

Targeting training

When athletes return to play after a significant period of rest or injury, their return should be slow and progressive. Acute and intense increases in the training regimen at the beginning of the season, prior to major competitions, or during injury recovery have been associated with recurrence or overuse injury. A slow progressive recovery program has the best opportunity for successful return to play without recurrence (Tables 10.4, 10.5 and 10.6). In addition to conditioning, coaches should also assure that athletes also have a gradual progression in skills from fundamental to more complex. This plan would avoid the risk of the immature baseball player throwing a curveball with poor mechanics or of the young cheerleader/gymnast attempting a stunt beyond her skill level and risking a catastrophic fall on her outstretched hand.

Targeting the athlete at risk

The at-risk athlete should also be screened at the time of his preparticipation examination for coordinated movement, strength and symmetry along the entire kinetic chain. Scapular dyskinesia can be assessed by inspecting the athlete from posterior and asking them to protract, retract, and elevate their shoulders with their arms at the sides, hands on their hips, and with their arms abducted 90° (Box 9.1). Any side-to-side asymmetry should be

Table 10.5 Interval rehabilitation program: tennis (Reinhold et al., 2005).

Week #	Monday	Wednesday	Friday
Week 1	12FH	15 FH	15FH
	8BH	8BH	10BH
	10-min rest	10-min rest	10-min rest
	13FH	15FH	15FH
	7BH	7BH	10BH
Week 2	25FH	30FH	30FH
	15BH	20BH	25BH
	10-min rest	10-min rest	10-min rest
	25FH	30FH	30FH
	15BH	20BH	25BH
Week 3	30FH, 25BH	30FH, 25BH	30FH, 30BH
	10 Serves	15 Serves	15 Serves
	10-min rest	10-min rest	10-min rest
	30FH, 25BH	30FH, 25BH	30FH, 25BH
	10 Serves	15 Serves	15 Serves
Week 4	30FH, 30BH	30FH, 30BH	30FH, 30BH
	10 Serves	10 Serves	10 Serves
	10-min rest	10-min rest	10-min rest
	Play 3 games	Play set	Play 1.5 sets
	10FH, 10BH	10FH, 10BH	10FH, 10BH
	5 Serves	5 Serves	5 Serves

*FH = forehand shots; BH = backhand shots.

Table 10.6 Interval rehabilitation program: golf (Reinhold et al., 2005).

Week #	Monday	Wednesday	Friday
Week 1	10 putts	15 putts	20 putts
	10 chips	15 chips	20 chips
	5-min rest	5-min rest	5-min rest
	15 chips	25 chips	20 putts/20 chips
Week 2	20 chips	20 chips	15 short irons
	10 short irons	15 short irons	20 med irons
	5-min rest	10-min rest	10-min rest
	10 short irons	15 short irons	20 short irons
	15 med irons	15 chips	15 chips
	5 iron off tee	putting ad lib	putting ad lib
		15 med irons	15 medium irons
Week 3	15 short irons	15 short irons	15 short irons
	20 med irons	15 med irons	15 med irons
	10-min rest	10 long irons	10 long irons
	15 short irons	10-min rest	10-min rest
	15 med irons	10 short irons	10 short irons
	5 long irons	10 med irons	10 med irons
	10-min rest	5 long irons	10 long irons
	20 chips	5 woods	10 woods
Week 4	15 short irons	Warm-up	Warm up
	15 med irons	Play 9 holes	Play 9 holes
	10 long irons		
	10 drives		
	15-min rest		
	Repeat		
Week 5	Play 9 holes	Play 9 holes	Play 18 holes

addressed with focused rehabilitation. Evaluation of core strength and coordination is also important. During the preseason screening evaluation, all overhead athletes should be asked to perform a single-legged squat on both a stable and an unstable surface (foam pad, balance board, mini-tramp). The observer should look for poor balance in the upper body with arm swaying or inability to maintain single leg stance, hyperflexion of the lumbar spine instead of a true knee squat, and gluteal weakness evidenced by knee internal rotation or dropping the contralateral pelvis (Figure 5.7). Any abnormalities discovered should be addressed with focused training and has been shown to reduce the incidence of elbow problems in athletes (Kibler & Sciascia, 2004).

Targeting early recognition

Educational programs may also target the reduction of injury incidence and severity. Athletes in throwing, weight-bearing and weight-lifting sports need to be educated to offer complaints of elbow pain when present. Delayed diagnosis can lead to poorer prognosis. For example, young gymnasts should never participate in the presence of undiagnosed pain for fear of making the pathology worse. Mild degrees of osteochondritis dissecans can be treated with rest and have a significantly better prognosis than advanced degrees of osteochondritis dissecans with loose bodies. Indeed gymnasts compared to all sports have the worst prognosis regarding return to sport when the osteochondritis dissecans is severe. Another example is the mature athlete with a prodrome of bicipital tendonitis or medial collateral ligament pain. Continued participation and loading can lead to complete rupture, while early treatment and rest may avoid the need of surgical intervention completely.

Focused, sport-specific injury prevention intervention plans should target the three most studied sports regarding overuse elbow injuries; golf, tennis, and baseball. These plans can easily be translated to other sports using baseball as a model for throwing sports, tennis as a model for racquet sports, and golf as model for stick sports.

Targeting golf

Golf has a surprisingly high rate of elbow injuries, particularly for the amateur athlete (see Table 10.1). The length of the golf club increases the force moment that magnifies the energy that crosses the elbow joint. As noted earlier, this mechanism has been associated with the development of golfer's elbow or a tendinopathy on the medial aspect of the elbow. Prevention centers on an increased awareness of the risk as well as improving the mechanics of the golf swing including impact. Avoid taking large divots. Optimize swing mechanics. Equipment modifications may also be helpful with more flexible shafts to absorb shock, appropriate grips for hand size, and broader head designs with peripheral weighting to maximize the sweet spot.

Targeting tennis

A majority of elbow injuries related to tennis are related to either repetitive varus forces with active wrist extension during the backhand or repetitive valgus extension overload during the serve. Reduction of the risk of tennis elbow begins with the proper equipment. The grip should not be too small placing the extensors on tension and at risk of injury. For beginners and intermediate level players, high tension racquets are unnecessary for success and may be avoided while skills are advancing. Oversized heads and other equipment designs that help to absorb the shock of impact or assure optimal contact may also be helpful. Counterforce bracing has also been popular to decrease the focal loads on the lateral aspect of the elbow. Many athletes have switched to a two-fisted backhand because it allows them increased power, more control, and reduced forces over the lateral aspect of the elbow. Athletes with a history of or at risk of tennis elbow should consider switching to a two-fisted backhand to diminish the loads.

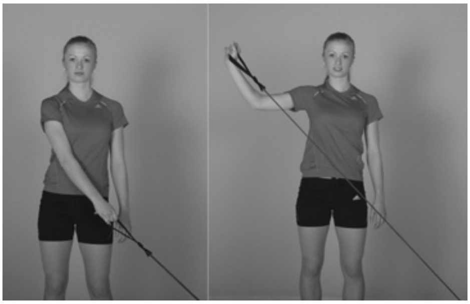
The next most common injury pattern in tennis players are related to the repetitive valgus-extension overload that occurs with overheads and the tennis serve. This pattern mimics that seen in throwing athletes. Strains or rupture of the medial collateral ligament, compression injuries of the capitellum, and posterior impingement lesions have been identified just like those seen in baseball. Indeed the severity may be magnified by the increased fulcrum provided by the additional racquet extension to the site of impact. Prevention plans include athlete education to optimize early identification and initiation of treatment; preparticipation screening identifying risks in both the elbow and the shoulder, conditioning programs that focus on every facet of the kinetic chain (Box 10.1). To avoid overuse elbow problems in the skeletally immature, an evaluation of the number of serves, overheads, and backhands performed in a given session or week may be of benefit. This has clearly been effective in reducing the risk of injury in skeletally immature throwers (Lyman et al., 2002; Dugas, 2006; Olsen et al., 2006). Indeed, there is a good support to this plan in skeletally immature throwers in little league baseball.

Targeting baseball and overhead throwers

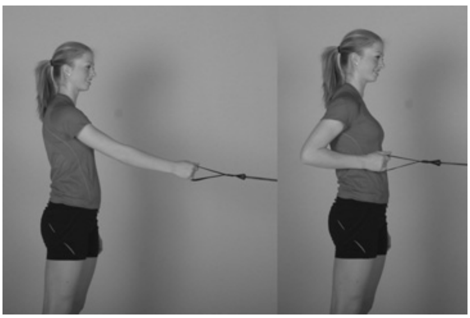
To begin targeting the throwing athlete, most athletes are placed on a routine program of rotator cuff strengthening, scapular stabilization exercises, core strengthening and posterior capsular stretches. Those with deficits are asked to participate in a supervised program until the deficits are corrected (Box 10.2). The second key intervention for overhead throwers is educating the athlete regarding overuse and monitoring the number of throws they perform and the amount of rest between each outing. This is especially true for the skeletally immature athlete. Controlled number of pitch counts per week and season with prescribed numbers of days or rest between outings has been directly correlated with reduced risk of elbow injuries in both the immature and the mature throwers (Table 10.7) (Lyman et al.,

Box 10.1. Injury prevention protocol for tennis

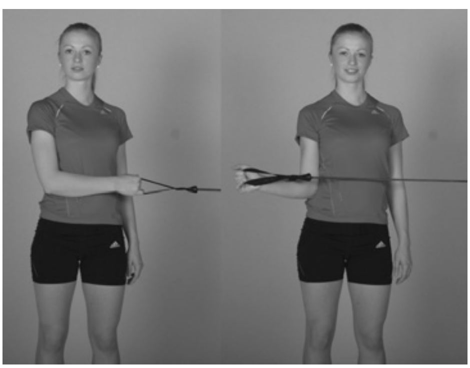
1. Low-to-high pull with resistance against weight or tubing
- Begin reaching low across body outside of contralateral foot
- Explosive lift the arm into full abduction and external rotation
- Slowly return to the first position
- Repeat 1–3 sets, 15–20 repetitions



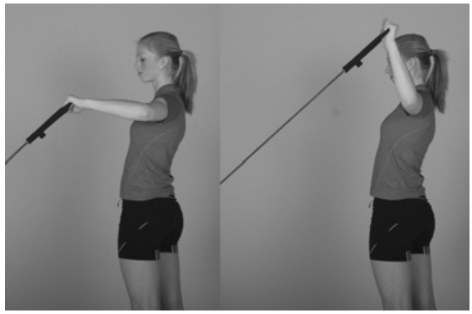
2. Straight arm rowing with resistance against weight or tubing
- Begin with arms straight in front with in line tension
- Pull arms into extension while squeezing shoulder blades together as if rowing a boat
- Repeat 1–3 sets, 15 repetitions



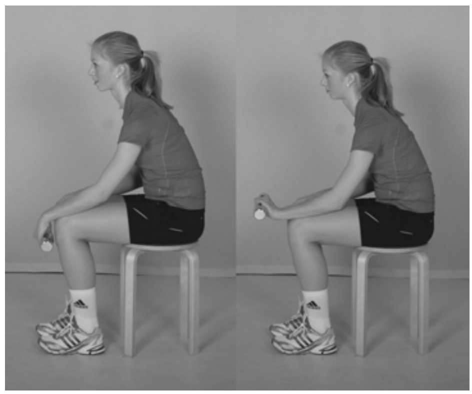
3. Standing external rotation with resistance against weight or tubing
- With the arm at the side & 0° of abduction & neutral rotation
- Externally rotate against resistance
- 1–3 sets, 15–20 repetitions



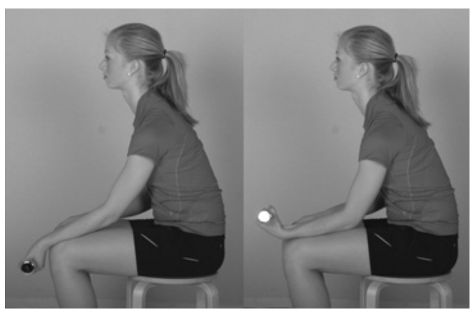
4. 90–90 external rotation with resistance against weight or tubing
- Begin with the arm at 90° of abduction and neutral position
- Externally rotate against resistance
- 1–3 sets, 15–20 repetitions



5. Wrist extension (strengthening) with resistance against weight or tubing
- While seated and forearms resting comfortably on thigh
- Extend wrists from a flexed, palm down position to full extension
- 1–3 sets, 15–20 repetitions



6. Wrist flexion (strengthening) with resistance against weight or tubing
- While seated and forearms resting comfortably on thigh



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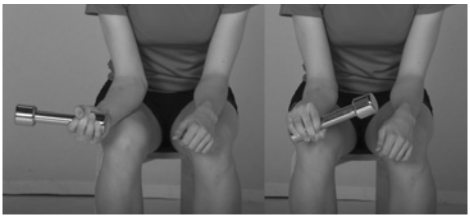
Box 10.1 (Continued)

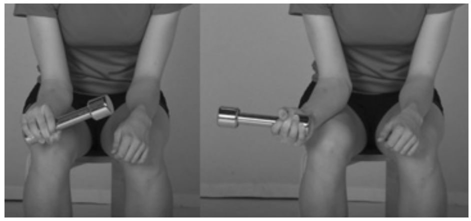
– Flex wrists from a extended, palm up position to full flexion
– 1–3 sets, 15–20 repetitions

7. Forearm pronation with resistance against weight or tubing
– While seated and forearms comfortably resting on thigh
– Wrap resistance tubing around hand so that it exits on the thumb side of the hand and secure the free end
– Hand should be positioned palm up until resistance is felt in tubing



– Twist forearm palm down against resistance
– 1–3 sets, 15–20 repetitions

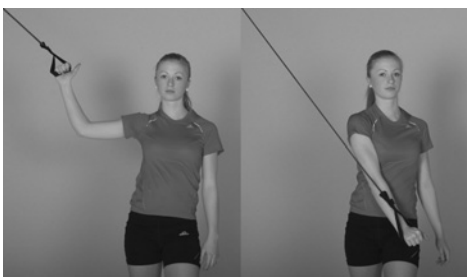
8. Forearm supination with resistance against weight or tubing
– While seated and forearms comfortably resting on thigh
– Wrap resistance tubing around hand so that it exits on the thumb side of the hand and secure the free end
– Hand should be positioned palm up until resistance is felt in tubing
– Twist forearm palm down against resistance
– 1–3 sets, 15–20 repetitions.



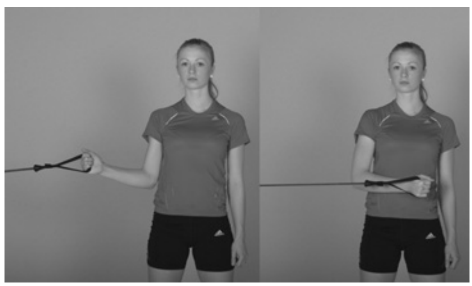
Source: Shoulder and elbow injury prevention protocol from United States Tennis Association (www.playerdevelopment.usta.com).

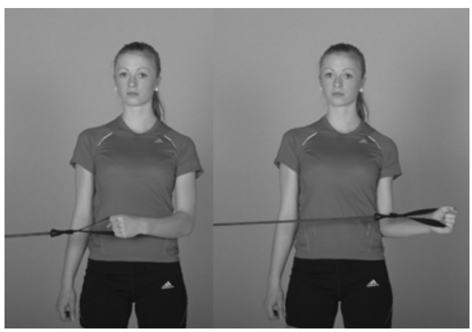
Box 10.2 The thrower's 10 exercise prevention program

1. Diagonal pattern D2 extension/flexion
– Stand, using resistance tubing begin with arm in full abduction and external rotation and pull tubing down and across the body to the opposite side of the leg
– Using resistance tubing begin with arm crossed over body bear opposite hip and pull tubing into full abduction and external rotation position



2. External/internal rotation at 0° and 90° of abduction
– Stand, using resistance tubing begin with arm in fully internally rotated position, first with arm at 0 abduction then with arm in 90° of abduction
– Pull on resistance while rotating into full external rotation
– Repeat above but begin with arm in full external rotation and pull on resistance at both 0° and 90° of abduction into full internal rotation





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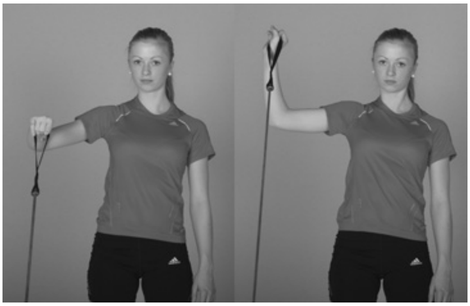
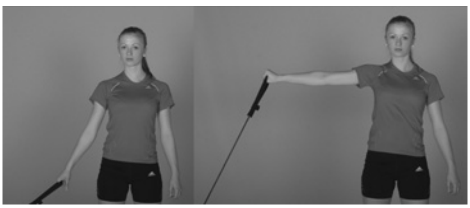
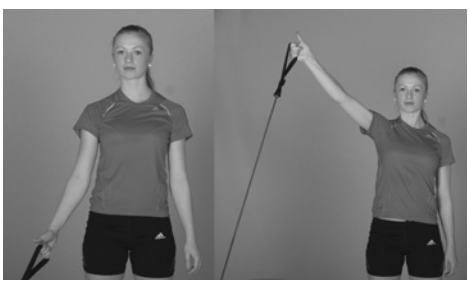
Box 10.2 (Continued)



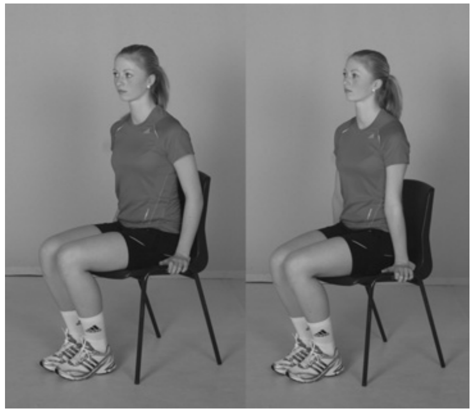
3. Shoulder abduction to 90°
- Stand holding a 5 pound weight or against resistance tubing begin with arm at side then abduct the shoulder to 90° with elbow in full extension



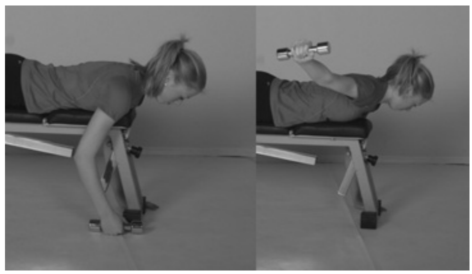
4. Scaption, internal rotation
- Stand with arm at side and elbow straight and thumb up
- Raise arm to shoulder level at 30° angle in front of body (in plane of scapula)
- Hold for 2 s, lower slowly



5. Press-ups
- Seated on a chair or table, place both hands firmly with palms down
- Slowly push downward on both hands to elevate your body
- Hold for 2 s, lower slowly

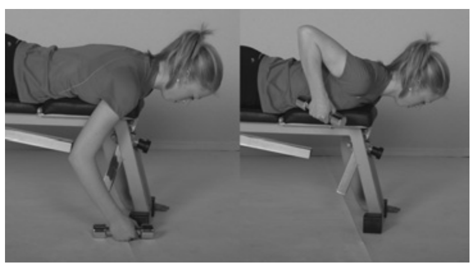


6. Prone horizontal abduction
- Lie on table face down with arm hanging to floor, hold barbell weight or against tubing resistance, extend the arm laterally, parallel with the floor
- Hold 2 s, lower slowly
- Repeat both in neutral and full external rotated positions



7. Prone rowing

Lie on table face down with arm hanging to floor and holding barbell weight, pull backwards, flexing the elbow as if rowing
- Bring the dumbbell up as high as possible
- Hold for 2 s and slowly lower

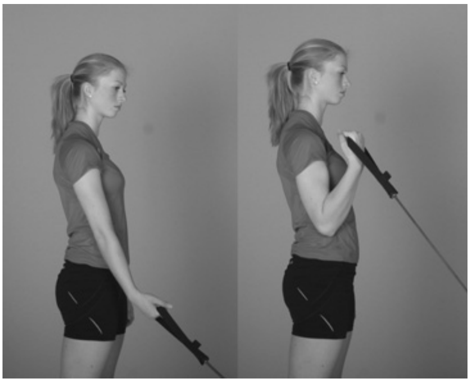


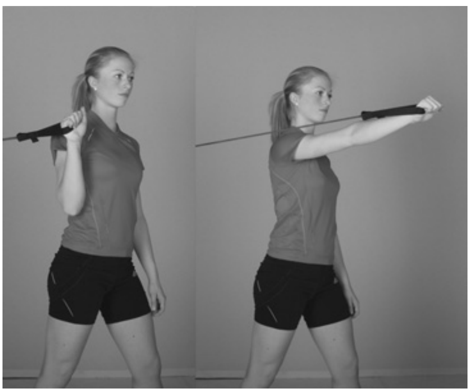
(Continued)

Box 10.2 (Continued)

8. Push-ups
Place hands no more than shoulder width apart. Push up as high as possible rolling shoulders forward after elbow lock straight

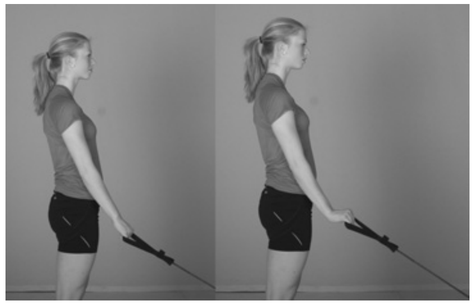
9. Elbow flexion/extension
- With arm against side and in full supination, lift barbell weight or against resistance tubing, hold 2 s and lower slowly
- Lift arm overhead and support elbow.

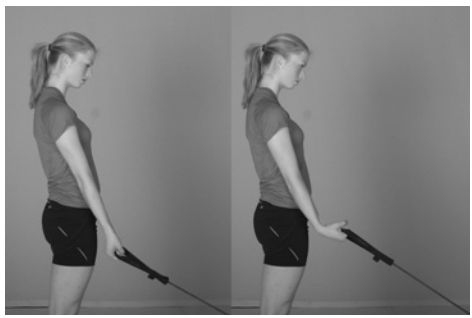




- Straighten elbow over head against resistance or barbell weight. Hold 2 s and slowly lower

10. Wrist extension/flexion, supination/pronation
- Supporting the forearm on a table with the palm faced down, extend the wrist against weight or tubing resistance
- With the palm faced up, flex the wrist against weight or tubing resistance
- With the wrist in neutral position use a hammer, off-centered weight, or tubing to resist placing the arm in to a palms-up position
- With the wrist in neutral position use a hammer, off-centered weight, or tubing to resist placing the arm in to a palms-down position





Source: From James Andrews, American Sports Medicine Institute. Video illustrations available at http://www.asmi.org/sportsmed/throwing/thrower10.html.

2002; Dugas, 2006; Olsen et al., 2006). These guidelines are based on performance pitch counts and not tosses from other positions; however, the clinician should ask the athlete if they participate in more than one league, pitch at full speed between games, or perform showcase events. In any of those cases, the full speed pitch count should be applied to the pitch count guidelines. Prevention guidelines for the skeletally immature also include recommendations regarding the appropriate age to add certain types of pitches (Table 10.8). It should be emphasized to the young thrower that a proper throwing mechanic

Table 10.7 Pitch count guidelines in Youth Baseball from USA Baseball and the American Sports Medicine Institute.

Age group	Throwing program
9–10 year olds	
	– 50 pitches per game
	– 75 pitches per week
	– 1000 pitches per season
	– 2000 pitches per year
11–12 year olds	
	– 75 pitches per game
	– 100 pitches per week
	– 1000 pitches per season
	– 3000 pitches per year
13–14 year olds	
	– 75 pitches per game
	– 125 pitches per week
	– 1000 pitches per season
	– 3000 pitches per year

Table 10.8 Guidelines for the institution of pitch types in Little Leaguers from USA Baseball and the American Sports Medicine Institute.

Pitch type	Age (years)
Fastball	8–10
Change-up	10–13
Curveball	14–16
Knuckle ball	15–18
Slider	16–18
Fork ball	16–18
Screwball	17–19

and not some new tricky pitch will most improve their performance and outcomes.

Take-home message

The elbow serves an integral role in many sports making the importance of maintaining optimal function and avoiding injuries is an important goal for athletes. Not all elbow injuries, particularly many of the traumatic ones, are avoidable. Nonetheless, the incidence of those may be reduced by following the rules of play, optimizing equipment, and avoiding fatigue for at risk athletes. The best target for injury prevention of elbow injuries should target the repetitive overuse injuries. For children, reducing exposure by imposing pitch counts or throwing limits can reduce the incidence of injury and early identification and rest can prevent them from becoming more severe. A simple rule for coaches of skeletally immature athletes is that they should not play through pain. The return to play for all injured elbows should be gradual and progressive. In thrower's this is done via a throwing protocol which begins with light tosses and progresses in distance and speed. If the athlete returns too quickly he risks reinjuring his elbow. A universal program to reduce the risk of elbow injuries must look beyond the elbow joint itself and include training and coordination of the entire kinetic chain. Preseason screening programs to identify core weaknesses including such things as single leg squats on unstable surfaces and evaluation of scapular dynamics can help to identify the athlete at risk.

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Chapter 11

Preventing injuries to the head and cervical spine

Paul McCrory[1], Michael Turner[2] and Andrew McIntosh[3]

[1]Centre for Health, Exercise and Sports Medicine, University of Melbourne Parkville, Australia
[2]Chief Medical Adviser, British Horseracing Authority and Lawn Tennis Association; formerly CMA to British Olympic Association and Snowsport, UK
[3]School of Risk and Safety Sciences, The University of New South Wales, Sydney Australia

Epidemiology of head and cervical spine injuries in sports

Sports involving collision, body contact, projectiles, and/or high speeds are associated with a risk of head and neck injury. The range of potential head and neck injuries—from facial lacerations to intracranial hemorrhage, from mild neck strains to spinal cord lesions makes this area of injury management particularly difficult.

Fortunately, most sports-related head and neck injuries are mild. However, severe and sometimes fatal injuries do occur which makes the need to prevention of such injuries critical. It is worth also observing that head and neck injuries do not always occur on the sports field; a child spectator died in 2002 after being struck in the head by an ice hockey puck in the United States and in 2001, a track marshal was killed during a Formula 1 championship race.

These tragic examples indicate that injury prevention must be multi-faceted, addressing, in these cases, the "built" environment, training, and supervision.

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Pathophysiology of head and neck injury

Non-penetrating brain injury (or closed head injury) may be divided into primary and secondary injuries. Primary injury is the result of mechanical forces producing tissue deformation at the moment of injury. These deformations may result in either functional disturbance or structural disruption of cell membranes. The injury may also set in train a complex cascade of biochemical, immunological, or coagulopathic changes that may cause further damage.

Secondary damage occurs as a complication of primary injury and includes hypoxic and ischemic damage, brain swelling, hydrocephalus, and infection. Sports concussion by definition has no macroscopic neuropathological damage and it is speculated that the critical physiological change occurs at the cell membrane level. There has also been recent evidence to suggest a significant genetic basis to head injury outcomes (Aubry et al., 2002; McCrory et al., 2005).

Concussion and mild traumatic brain injury

Sports concussion has been defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces (Aubry et al., 2002; McCrory et al., 2005). Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an "impulsive" force transmitted to the head.

2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.

3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.

4. Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course.

5. Concussion is typically associated with grossly normal structural neuroimaging studies.

In Table 11.1, the incidence of concussion is presented using common exposure risk. It can be seen that sports where high velocity impacts (e.g., equestrian sports) occur, the risk of head injury is the greatest.

Table 11.1 Risk of concussion in elite sports.

Sport	Incidence per 1000 h of exposure[1]
Horse racing	25.0
Kickboxing	4.8
Australian football	4.2
Professional boxing	3.9
Rugby union football	3.9
Cricket	2.0
Ice hockey	1.5
Football/Soccer	0.4
American football	0.2
Skiing/snowboarding	0.05
Baseball	0.0043

The numbers reported are average estimates based on the studies available.
[1]Incidence is reported for adult, competitive athletes as the number of injuries per 1000 h of competition.

Catastrophic head and spinal cord injury

Catastrophic head and spinal cord injury occur in virtually all sports. In total 497 persons have died while playing American football in the United States since 1945; of these 69% died from fatal brain injuries and 16% from spinal cord injury (Levy et al., 2004). Data from the US Catastrophic Injury Registry suggests that the incidence of catastrophic head and spinal cord injury has been dropping since the late 1960s and the effect of the introduction of rule changes (e.g., mandatory helmet use, banning spear tackles) in the 1970s led to no appreciable change in the downward trend of injury rates.

Even though the overall rate of spinal cord injury in rugby is low, there is a likely risk in rugby associated primarily with the tackle and scrum. Although this is suggested by retrospective studies and theoretical modeling, no prospective study of rugby spinal cord injury has been performed before and after the introduction of rule changes to reduce scrum-related injury. Studies of "spinal" injury in rugby union demonstrate that the scrum and tackling constitute high risk injury mechanisms for non-catastrophic neck injury. However, the number of spinal cord injuries is too low in the study to provide a meaningful statement as to spinal cord injury risk due to these mechanisms (Fuller et al., 2007). Interestingly there is some data to suggest that the spinal cord injury rate differs significantly with age, with schoolboy rugby players having spinal cord injury rates approximately one-third that of adult players.

With regard to fatal head injury, the only comparative data between sports and/or recreational activities was performed in the United Kingdom a number of years ago (Lyens et al., 1984). The findings are somewhat surprising insofar as sports that have a perception of high injury risk (e.g., boxing) have surprisingly few fatalities, whereas aquatic sports have relatively high fatality rates (Table 11.2).

Most commonly played sports (with the exception of equestrian sports) have relatively low fatality rates and although a fatal event may expose an underlying anatomical or physiological abnormality in the individual concerned there is no conclusive evidence that pre-event screening (e.g., MR or CT brain scans in boxers) will prevent fatalities.

Table 11.2 Sport-related fatalities in England and Wales.

Sport	Fatality rate[1]
Climbing/mountaineering (excl. hiking and fell walking)	>793
Air sports	>640
Motor sports	146
Water sports/windsurfing (excl. sailing and fishing)	67.5
Sailing/yachting	44.5
Fishing	37.4
Horse riding (excl. hunting and polo)	34.3
Rugby (union and league)	15.7
Boxing/wrestling	5.2
Football (Soccer)	3.8
Cricket	3.1

[1]Fatality rates per 100,000,000 occasions (days) of participation.

Key risk factors: how to identify athletes at risk

In general, risk factors for injury can be classified into either intrinsic or extrinsic (Meeuwisse, 1991; Milburn, 1993). Intrinsic or internal factors relate to innate qualities of the individual such as their age or genetic make-up. Conversely, extrinsic factors are those related to the environment. Analysis of the epidemiological literature reveals a number of risk factors, which may be associated with increased risk of sports concussion (Table 11.3). Other than for sports concussion, there is surprisingly little published prospective risk factor analysis for catastrophic head and neck injury.

Injury mechanisms

General

Head and cervical spine injuries in sport arise mainly due to impacts either with opposing players, the ground or equipment. Participants are exposed to impacts in many sports, for example, football (of all types), projectile sports (cricket, baseball, and hockey), high-speed winter sports, aerial sports (gymnastics), martial arts, and wrestling.

Table 11.3 Summary of intrinsic and extrinsic risk factors in sports concussion.

Proposed risk factors	Comments
Intrinsic factors	
Age	Confounding factors include (a) increased exposure with increasing age and (b) potential mismatch of ability players in junior competitions.
Genetic predisposition	The current literature is based largely on studies involving case series and retrospective designs in patients with moderate to severe head trauma.
	In studies where potential confounding factors are controlled (e.g., age, GCS score on admission, neurosurgical management), no association is found between apolipoprotein E4 genotype and outcome (Nathoo et al., 2003).
Behavior ("risk compensation")	Use of protective equipment such as helmets, may result in higher risk taking behavior.
Extrinsic factors	
Characteristics of the playing surface	The main confounding factor is ground hardness, which may impact on speed of the game and subsequent forces of collisions and risk of contact injuries.
Playing position	The common trend is that positions of highest risk tend to reflect those in which collision rates and velocity of impact are highest.
Level of play	Confounding factors include (a) increased potential for mismatch of player size and ability at some lower levels and (b) modified rules, which may limit player contact.
Biomechanics of head impact (site, closing velocity, and duration of impact)	Significant limitations include (a) not all concussions are clearly seen on video footage and (b) mathematical assumptions are made in estimates of acceleration.
Previous injury	Most studies rely on retrospective recall of concussion, which is known to be inaccurate. Furthermore, important confounding factors such as style of play (e.g., tackling technique) are often overlooked.

The mechanics of head and cervical spine injuries have been studied extensively using mathematical, experimental, and observational methods. These studies arose initially out of the need to prevent blunt trauma amongst road users and to assess the effects of pilots operating in environments with high "g forces." Due to the recognition that sports participants experience many similar injuries to road users and that the loading patterns can be similar, there has been a transfer of knowledge and theoretical approaches into sport.

In simple terms, the head and neck are injured due to exposure to forces that exceed the "strength" of the brain, skull, blood vessels, and vertebrae. The magnitudes of the force and/or other relevant characteristics, moment, and acceleration, are determined largely by the energy transfer in the impact. Other factors are important such as, anatomical point of impact, the shape and stiffness of the impacted/impacting object, the direction of loading; amount of translational and/or angular motion of the head, and, for the neck, the presence of axial loading. The strain that results from these forms of loading is the primary cause of injury. However, strain is difficult to measure in these situations.

The tackle in rugby, Australian and American football, and body checking in ice hockey are associated with risks of minor to severe impact injury, including spinal cord injury. In rugby, approximately half of all injuries arise in the tackle.

Factors that may give rise to injury risks in the tackle include: high tackles; high velocity tackles; tackles in which the tackler may have been in the peripheral vision of the ball carrier; "big hits" in which the ball carrier is tackled by more than one player ("grapple" tackle is an example of a controversial multiplayer tackle in rugby league) (Figure 11.1); and, a general lack of skill for the tackler. Apart from high tackles and spear tackles, where the ball carrier is speared head first into the ground, the other types of tackle are legal.

Biomechanics of head injury

How do head impacts in motor vehicle accidents compared with those in football? It is very difficult to measure or simulate the complex dynamics of these real-life impact events because of energy attenuation by muscle, joint, or connective tissue forces applied through the neck to the head, and soft tissue deformation.

A number of studies using video analysis, finite element analysis and injury modeling have attempted this in both Australian and American football. The basic biomechanical injury mechanisms however, are the same, namely; forces applied directly to the

Figure 11.1. Examples of "grapple tackles" in rugby league where multiple opponents tackle the ball carrier and attempt to get their arms around the neck while flexing the head forward

head or via the trunk and neck accelerate the head producing internal stresses within the brain, which in turn may result in anatomical or physiological injury. The resultant brain injury is related to the magnitude of the impact force, the location of impact and the resultant head and brain acceleration. Loading of the skull can deform it leading to fractures, brain contusions, pressure effects, and/or intracranial hemorrhages.

Interestingly, biomechanical data from sports head injury studies show that in the majority of impacts the resulting head accelerations are not trivial but they are lower than those observed in motor vehicle accidents. Linear head accelerations in the order of 100g are associated with concussion in sport, whereas the probability of skull fracture or intracranial haemorrhage becomes very high with accelerations greater than 200g. Angular acceleration has been associated with axonal injury and bridging vein rupture that leads to subdural hemorrhages. Strain rate and intracranial pressure effects during impacts have also been identified as possible causes of brain injury. These are difficult to measure directly, but can be approximated using computer simulations.

Biomechanics of spinal cord injury

Sport-related spinal cord injury is often due to a combination of axial compression of the cervical spine and either flexion or extension (Figure 11.2). The resultant

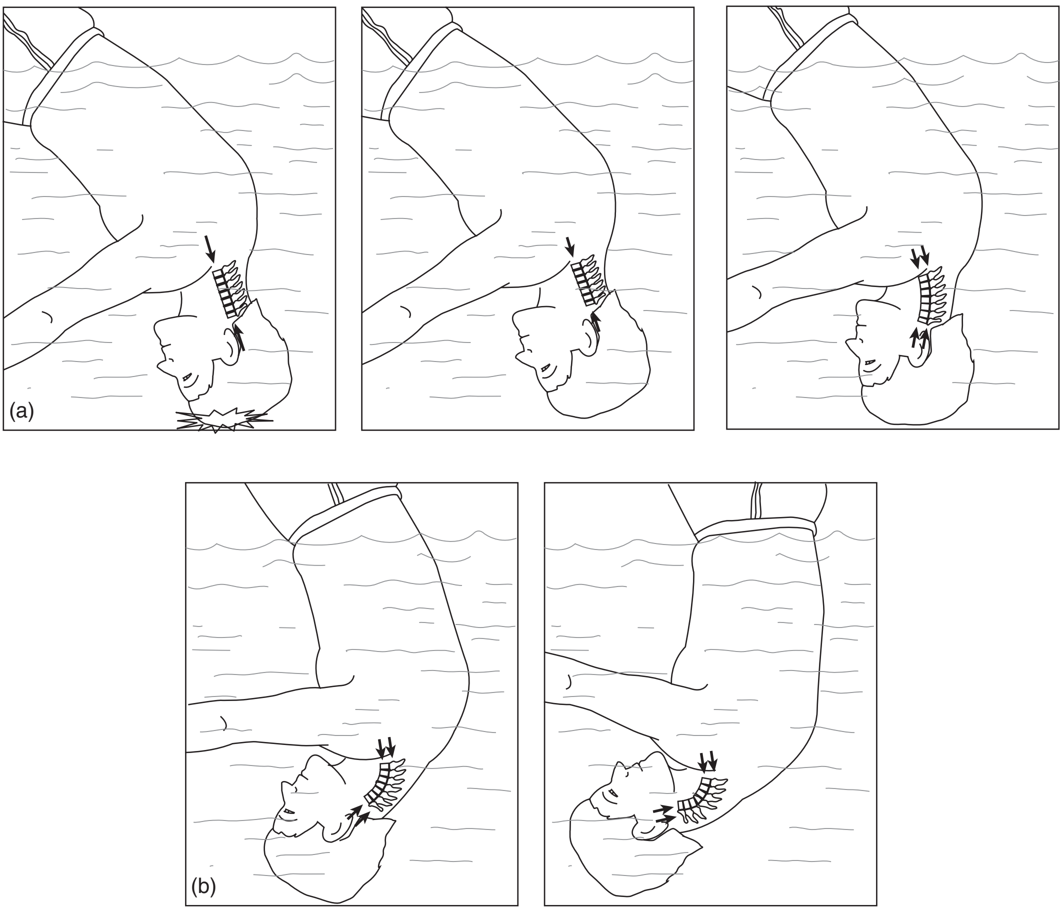

Figure 11.2. Spinal injury mechanisms: (a) the key mechanism in sport-related cervical spine injuries is axial load and forward flexion of the neck as illustrated in a diver; (b) Axial load and forward flexion of the neck results in vertebral compression and anterior wedging of the vertebral bodies

force compresses the vertebral segments and if the tolerance of the vertebrae is exceeded, a "burst fracture" and/or uni-/bi-facet dislocation occurs which then damages the cervical spinal cord through direct compression.

Examples of sport-specific mechanisms are given later.

The rugby scrum

The rugby scrum has received substantial attention over the years with regard to spinal cord injury. A rugby scrum consists of two opposing packs of eight players divided into the three front row, two back row, and three "loose" forward. The front rows of each team's scrum pack engage through their heads and shoulders in a forceful driving motion. This can result in high axial compressive neck forces combined with a bending moment and/or shear forces. During the 2003 Rugby World Cup there was one case of cervical dislocation during a scrum engagement that was a career-ending injury.

Milburn et al. measured the forces applied to an instrumented scrum machine, and found that the total horizontal forward force on engagement ranged between 4.4 kN for high school players and 8 kN for the Australian national team (Andersen et al., 2004). After the initial engagement, the sustained force reduced by approximately 20%. The forces on engagement have the potential to exceed axial neck load and bending moment tolerance limits. As a result, scrum laws for under 19 year olds are now designed to eliminate an impact on engagement and permit each front row to orient itself well, thus reducing neck loads. No study has reported on the effectiveness of the "under 19 law," although it is widely viewed as being successful and these principles are influencing future developments in the scrum.

Head and neck injury prevention

Injury prevention methods have been categorized under headings drawn from Haddon's Matrix (Table 11.4). Examples from the literature have been used to demonstrate the effectiveness of each method. For these methods to be successful, they must either be able to minimize the energy involved in impacts and collisions or reduce the forces applied to the body to levels that can be tolerated without injury. In the context of formal sports it is possible to eliminate some injury risks by pre-crash measures; elimination or substitution of hazards, or engineering methods. Sensible removal of structures from the playing field, and the provision of barriers between the playing field and spectators are obvious engineering methods for preventing injuries.

Administrative controls (Laws and Rules)

Rules are one of the most common methods used to prevent injury, however there have been few structured intervention studies that have identified the benefits associated with specific rules. If the rules are not followed, for example, spear tackling, illegal scrum engagement, or high tackles, the enforcement of the rule occurs after the potential injurious event. Post-injury penalization of players might serve to prevent the illegal play in conjunction with a pre-injury explanation of the rules, their rationale, and development of a safe culture.

Body checking in ice hockey, especially involving the head, has led to a concern that this form of contact should be eliminated through rule changes due to its association with head injury. As with spear tackling in American football, which was made illegal, there is a view that the use of helmets has increased hazardous play due to players' perceptions that they are at a lower risk of injury, often referred to as risk compensation. In American football, the intentional use of the helmet or faceguard as the primary point of contact has also been made illegal. Apart from reducing tackle-related injuries through rules, no study has reported on the effects of tackle training as a method for preventing injury.

Head injury in football (soccer) has been investigated recently. While heading the ball does not appear to cause concussion per se, the contest for the ball in the air does. During the contest, players can be struck in the head by the opponent's elbow, shoulder, or head, causing injury (Figure 11.3). Approximately 50% of all concussions were attributable to this mechanism (Cantu, 2000). As a direct

Table 11.4 Injury prevention matrix applied to sporting head and neck injury prevention: potential measures to prevent injuries.

	Pre-impact	Impact	Post-impact
Athlete	Tackling technique Neck strengthening Preparticipation screening	Technique: Good head position in tackle, good body posture in scrum engagement	Provide appropriate medical care Education Correct rehabilitation
Surroundings	Preparation and inspection of playing area and surface	Improve padding of goalposts Develop low impact sideboards	Access for emergency medical coverage
Equipment/ other athletes	Training Availability of personal protective equipment	Improve energy attenuation of helmets/head protectors and mouthguards Improve impact characteristics of ball Teach opponents to disengage if spinal injury is called	First-aid equipment Spinal stretcher Ambulance
Administrative	Medical review Player exclusion rules and return to play guidelines Team culture, competitiveness, risk awareness and compensation Rules of the game	Enforcement of rules	Removal of player from field Post-match penalization of dangerous player Injury management guidelines

Figure 11.3. Arm to head contact is the cause of over 50% of all concussions in football (soccer)

result of this research, FIFA modified the playing rules before the 2007 World Cup to make contact to an opponent's head with the elbow/upper arm during such heading contests a "red card" offence.

Preparticipation screening for head and neck injury

Unlike most sporting injuries, head and neck injuries do not have clear-cut risk factors that have been conclusively shown to influence either incidence or the outcome of injury (Table 11.3). Because of this most "risk factors" are theoretical in their application. Preparticipation screening while commonly advocated relies more on clinical common sense than the weight of scientific evidence.

One such method for preventing head and neck injury requires participants to undergo medical screening programs to identify players at risk of injury due to anatomical abnormalities (e.g., MR or CT brain scan), pre-existing brain injury (e.g., neuropsychological testing), or genetic markers (e.g., ApoE). Although intuitively sensible, it is important to realize that excluding player participation based on this approach may not be scientifically or medicolegally defensible.

In some situations, congenital spinal canal stenosis has been postulated as a risk factor for cervical cord injuries. Although the risk of future cord injury may be increased when canal stenosis is present and the athlete has previously sustained a cord injury, this increased risk cannot be quantitated with any certainty (Ackery et al., 2007). Furthermore, the risk of future cord injury in an asymptomatic athlete with canal stenosis is unknown at present. Advice regarding the risk of injury in this latter situation is at best anecdotal and no intervention studies are reported in the literature.

Training

Training to improve strength, fitness, individual and team skills is an accepted part of sport. While training programs have been shown to reduce lower limb injury, for example, the benefits of neck strengthening, skills or fitness on reducing head and neck injury have not been formally addressed. Considering the high associations between body contact and injury in American football, rugby, and ice hockey, it is possible that skills may theoretically reduce injury. Improving tackling skills in rugby, for example, head placement, may eliminate some accidental head impacts. Skills to track a ball, avoid ball contact, and mishits may also help to reduce neck and head injury, however they have not been formally assessed.

Environment: ground hardness and surface

Australian Rules Football is a fast, kicking and running game played at professional and amateur levels across Australia and associated with a high rate of concussion (Table 11.1). Recent studies have debated whether ground hardness is a direct factor in the etiology of injury or whether it indirectly contributes to higher injury rates as it enables higher running speeds and higher energy impacts. With regard to direct head impacts and concussion, various studies have noted significant differences in the impact energy attenuation properties of grass compared to artificial surfaces.

Personal protective equipment: helmets

Helmets and padded headgear are used in many projectile and contact sports to prevent head injury. Recent published meta-analysis studies of pedal cycle helmets in transport and recreation have confirmed the fact that light weight helmets are effective in preventing head and facial injuries in cyclists.

In some sporting competitions it has become mandatory to wear a helmet and/or faceguard, for example, baseball, softball, American football, ice hockey, as well as competitive alpine skiing and snowboarding. Helmets in American football and ice hockey have evolved from padded headgear to helmets comprising a hard shell, a liner, and a faceguard. Canadian and NOCSAE standards for ice hockey and football helmets, respectively, were established in the early 1970s. Recently, there has been much debate over the use of padded headgear in soccer.

Helmets are designed to attenuate the impact energy and distribute the impact force applied to the head. If a helmet can reduce the head impact force and head's acceleration to below relevant tolerance levels and under sport-specific impact scenarios, then a helmet can function to reduce the risk of brain injury.

The results of published studies show that all of the currently available commercial padded headgear for rugby and Australian football has a very limited ability to reduce concussive impact forces based on existing head injury models. Even if the more generous injury thresholds are applied to the data, all headgear tested lose any protective capacity once the impact energy is greater than 20J. This is reflected in randomized controlled trials of headgear in rugby and Australian football showing a lack of efficacy in concussion prevention with soft-shell helmets.

Studies of the effectiveness of helmets in sports where the use (other than in alpine racing) is not mandatory are emerging (Table 11.5).

While alpine sport injuries appear to be increasing over time, the use of helmets to prevent head injuries is associated with a 22–60% reduction in head injury rates (McCrory & Turner, 2005). The greatest limitations to the widespread application of protective helmets in these sports are the lack of an internationally accepted helmet standard, the availability of helmets and the variable fitting of helmets, especially with children.

Protective equestrian helmets are also widely recommended. Such helmets need to be certified to an appropriate materials testing standard. At

Table 11.5 Levels of evidence regarding helmet effectiveness.

Sport	Effect of helmet use on concussion incidence	Level of evidence	Comments
American football	Inconclusive	III	
Pedal cycling	Reduction	I	Ecologic or observational only
Ice hockey	No change	II	
Cricket	Unknown	IIII	Lab evidence only
Rugby	No change	I	High-quality RCT
Skiing	Reduction	II	Several high quality case control studies
Australian football	Unknown	II	One underpowered study only
Soccer	No change	III	Observational only
Equestrian	Unknown	III	Indirect evidence only

present, regulatory authorities mandate the use of helmets and body protectors in professional competition. It is recommended that an approved safety helmet be worn at all times when mounted. The British Standard (EN 1384.1996) is designed for competitive riding and is compulsory for professional jockeys and similar standards for horse riding helmets exist in other countries. Interestingly, since helmets were made compulsory for professional jockeys in 1993–1994, no significant changes in concussion rates have been observed. The numbers of fatal brain injuries over the same time period are too small to be adequately analyzed in this regard.

Indirect evidence exists that head protectors may play a role in injury reduction at least in non-professional equestrian riders. Both United States and United Kingdom data showed a fivefold drop in horse-related injury presentations between 1971 and 1992, due largely to a reduction in head injury presentation. Although not a causal relationship, this change was associated with an increase in helmet use over the same time period. Strategies to increase helmet use in riders have been studied extensively (Marshall et al., 2003).

Research to date, both field and laboratory, indicates that padded headgear (soft-shell helmets) does not reduce the incidence of concussion or serious head injury in Rugby Union football however it seems to reduce superficial injuries. Similarly the data from football (soccer) and Australian football suggests that the currently available helmets are unlikely to reduce concussion incidence.

Studies of the effectiveness of cricket helmets have been confined to the laboratory and indicate that the level of protection is greatly reduced with high-speed ball impacts.

Personal protective equipment: mouthguards and face shields

The use of correctly fitting mouthguards and face masks can reduce the rate of dental, facial, and mandibular injuries. In the case of face shields, there is evidence that they also reduce the rate of concussion whereas randomized controlled trials have demonstrated that mouthguards have little or no effect on reducing concussions and any suggested benefit for the prevention of brain injury is largely anecdotal.

Equipment: baseball

In baseball, softer balls have been used to reduce the risk of head injury in comparison to standard balls. Marshall et al. observed a 28% reduction in the risk of injury in baseball for games using the reduced impact ball compared to the standard ball (Nathoo et al., 2003). The softest impact ball was observed to be associated with the lowest risk of injury (48% reduction in risk) and the authors reported on a study noting that adult and child players found it difficult to identify the differences between standard and safety balls in pitching, throwing, and batting.

Neck muscle strengthening

It is often suggested that neck muscle conditioning may be of value in reducing impact forces transmitted to the brain. Biomechanical concepts dictate that the energy from an impacting object is dispersed over the greater mass of an athlete if the head is held rigidly. Although attractive from a theoretical standpoint, there is little scientific support for this viewpoint and no prospective published studies to support this approach. Video analysis of concussive injury seen in Australian football, rugby and soccer demonstrates that approximately 95% of concussive impacts are an accidental part of play and the players concerned were unaware of impending impact and hence unable to tense their neck muscles in an attempt to withstand the impact. This same issue may apply to protecting the spine.

Secondary injury prevention: post-impact measures

The role of injury prevention in the post-impact phase has not been adequately addressed in the published literature. It is intuitively likely that correct first-aid or paramedical management will reduce the risk of head or spinal cord injury complications. The management of the concussion or mild traumatic brain injury itself at best follows expert consensus guidelines (Level III evidence) in the absence of scientifically tested management strategies.

As the ability to treat or reduce the effects of concussive injury after the event is minimal, education of athletes, colleagues, and those working with them as well as the general public is a mainstay of progress in this field.

When head and cervical spine injuries are expected, the medical staff must have appropriate qualifications (e.g., AMST, EMST) and training to deal with them. They must have all the appropriate equipment to hand (hard collars, sandbags, lifting frame, and/or a spinal board) and have a method of rapid disposal on site (paramedic ambulance or helicopter) to an appropriate hospital (i.e., with neurosurgical trauma expertise). Administrative bodies supervising sideline doctors need to ensure that all medical staff have the appropriate and up-to-date qualifications.

Athletes and their health care providers must be educated regarding the detection of concussion, its clinical features, assessment techniques and principles of safe return to play. Methods to improve education including various web-based resources (e.g., www.concussionsafety.com), educational videos, outreach programs, concussion working groups, and the support and endorsement of peak sport groups such as FIFA, IOC, and IIHF.

The promotion of fair play and respect for opponents are ethical values that should be encouraged in all sports and sporting associations. Similarly coaches, parents, and managers play an important part in ensuring these values are implemented on the field of play and hopefully these may play a role in injury prevention.

Take-home message

Head and neck injury is common across all sports. Some sports (such as equestrian sports) have relatively high risks for participants. By contrast catastrophic injury is rare. Despite the significance and cost of head and neck injury, there have been few formal evaluations of injury prevention methods. Approaches that are considered successful or have been proven to be successful in preventing injury include: modifying the baseball; implementing helmet standards and increasing wearing rates in cycling, ice hockey, equestrian sports, and skiing and snowboarding; use of full face guards in ice hockey; changing rules associated with body contact; and, implementing rules to reduce the impact forces in rugby scrums. Soft-shell helmets and padded headgear appear in current designs to make little difference to rates of concussion. Neck injury has been addressed through laws and skill development, with little formal evaluation. Epidemiological, medical, and human factors research methods are required in combination with biomechanical and technological approaches to reduce further injury risks in sport.

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Chapter 12

Preventing tendon overuse injuries

Jill Cook[1], Mads Kongsgaard[2], Karim Khan[3] and Michael Kjær[4]

[1]Centre for Physical Activity and Nutrition Research School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia
[2]Institute of Sports Medicine, Bispebjerg Hospital, Copenhagen, Denmark
[3]Professor, Center for Hip Health and Mobility, University of British Columbia, Vancouver, Canada
[4]Department of Rheumatology, Institute of Sports Medicine, Bispebjerg Hospital, University of Copenhagen, Copenhagen, Denmark

Introduction

Tendons, force transducers interposed between muscles and bones, transmit the force of muscle contraction to bones to allow movement. Optimal tendon function is required for optimal performance. Tendons are subjected to large mechanical forces during movement but healthy tendons are well adapted to this peak demand.

Despite this peak load tolerance, tendon overuse injury (tendinopathy) is one of the most frequent injuries among elite and recreational athletes. Such overuse injuries most often affect tendons such as the Achilles, patellar, or supraspinatus tendon (Table 12.1). In sports characterized by forceful and explosive muscle contractions, the prevalence of patellar tendinopathy can reach 45–55% in populations of jumping athletes such as elite volleyball and basketball players. The prevalence of Achilles tendinopathy is also considerable in a variety of different sports such as running (about 10% of all athletes) and different ball games (e.g., football). Overuse injuries in the upper limb occur in athletes (throwing and racquet sports), but are also prevalent in an older population, particularly manual workers.

Overuse tendon injury presents as tendon pain, but tendon pathology and tendon pain can develop independently; pathology appears to precede pain in most cases. Tendons that rupture are often painfree, but have an extensive pathology and the force imposed on them is greater than the tendon integrity (Kannus & Jozsa, 1991). The mechanisms of tendon injury have not been identified and this greatly limits the ability of coaches and clinicians to prevent and treat tendon injuries.

Table 12.1 Prevalance of tendinopathy at various anatomical sites according to sport.

Sport	Anatomical region of tendon	Prevalence
Running	Achilles/iliotibial band/fascia plantaris	10% of runners
Football	Achilles	5–10% of all elite players
Volleyball	Patella	55% of elite-players
Basketball	Patella	45% of elite players
Track and fields	Patella/Achilles	10% of elite athletes
Badminton	Achilles/patella	5% of all players
Handball	Supraspinatus/other rotator cuff	5% of elite players
Baseball	Supraspinatus/other rotator cuff	20% of all players

The numbers reported are estimates based on the studies available.

In tendinopathy, where so little is known about the basics of the condition, prevention strategies are limited and not supported by evidence. To fully comprehend tendon injury mechanisms and the prevention of tendon injuries, it is important to understand tendon structure and function. Thus, we briefly introduce the structure, function

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and mechanics of normal tendon. Then we review the etiology of tendinopathy and propose opportunities for injury prevention.

Basic tendon structure

All muscles basically have two tendons, a short one at their proximal end (origin of muscle) and a somewhat longer one at their distal end (insertion of muscle) underlining that the mechanical properties of the tendons will have a great impact upon the function of the entire muscle–tendon–bone complex. Tendons and muscles join, and integrate, at the myotendinous junction—the site where the tendon infiltrates or interdigitates the muscle body to provide a large contact surface between the two structures. Distally, the tendon joins bone in the osteotendinous junction, a complex transition from soft to hard tissue. Because the muscle–tendon junction is primarily affected in a muscle strain injury, we will not consider the structure and function of the myotendinous junction in this chapter.

The structural design of different tendons varies substantially; some are short and thick, and others long and thin. Structure depends on the specific function of each tendon. Long tendons, such as the Achilles tendon, provide the body with energy-returning springs so that movement is energy efficient. Short, broad tendons, such as the quadriceps tendon, serve as pure force-transducers for their attached muscles.

Tendon matrix proteins: the building blocks of the tendon

The basic load-bearing element of tendon is collagen which exists as fibrils (Figure 12.1) that are embedded in a hydrated viscous proteoglycan-rich substance called the ground substance. Together, the collagen and the ground substance are called the extracellular matrix. The various components of the extracellular matrix are produced by the tendon cells (tenocytes, specialized fibroblasts) that are elongated spindle-shaped cells and are located between the collagen fibrils (Figure 12.1).
If you were to digest tendon collagen fibrils down to their core component you would come across

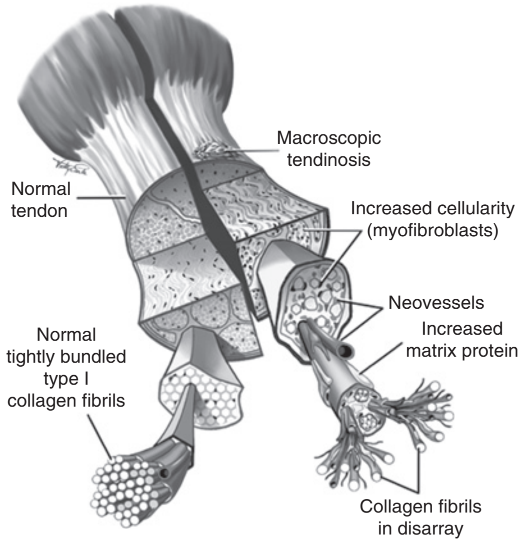

Figure 12.1. Bundles of type I collagen fibrils provide the load-bearing element of tendon (left side of the illustration). These fibrils are embedded in a hydrated viscous proteoglycan-rich substance called the ground substance. In pathological tendon, the fibrils lose their organized structure and disarray is obvious (right side of the illustration). Reproduced with permission from Clinical Sports Medicine (3/e) page 22, McGraw-Hill Publishing, Sydney, 2007.

triple helical collagen molecules. The individual collagen molecules inside the fibrils are interconnected and stabilized by cross-links thereby securing the force transduction along the fibril from one end of tendon to the other. Although there are more than 20 different collagen proteins, tendons predominantly consist of fibrillar type I collagen as well as smaller amounts of other collagen types including type II, III, and V. The various collagen molecules exhibit different mechanical properties and the general mechanical properties and function of the whole tendon is therefore highly influenced by the distribution of collagen types.

The matrix between the collagen fibrils is comprised of proteoglycans that are important for the alignment of collagen fibers. Proteoglycans are hydrophilic (attract water, hence the “swelling” in injured tendons, see later) and composed of polysaccharide chains of glycosaminoglycans that are bound to protein cores. Proteoglycans act as glue between the various collagen networks binding all the extracellular matrix molecules together. Proteoglycans also regulate matrix assembly and stabilize the extracellular matrix architecture. Further, proteoglycans control the hydration of the extracellular matrix and spacing between collagen fibrils and they bind various growth factors to regulate the tendon milieu. Together with other glycoproteins such as elastin, fibronectin, and laminin, the collagen and ground substance create a meshwork that does not rely on single molecules but rather on the polymers and networks that the molecules create.

The architecture of the tendon

The structural properties of the collagen fibril determine the mechanical properties of the tendon. This means that small fibrils increase the elastic properties and larger fibrils increase the strength via greater cross-sectional area and increased numbers of intramolecular cross-links. Approximately 95% of the fibers run longitudinally with the tendon orientation. Tendon fibrils can span the entire tendon length which implies that the tendon mechanical properties including strength and stiffness are highly dependent upon the dimensions and composition of the single fibrils. However, other factors such as collagen-type distribution, inter- and intra-fibrillar interactions as well as total tendon cross-section are important for the overall function and strength of tendons.

The intrafibrillar cross-linking of collagen molecules is an important mechanism for integrity between collagen molecules that contribute to the strength and force-transducing capability of the tendon fibril. Increased cross-linking increases tendon stiffness and elastic modulus, reduces the failure strain but does not appear to significantly affect rupture stress. Tendons in older individuals have an increase in non-enzymatic cross-linking in the form of glycation (incorporation of sugar) and this increases tendon stiffness.

Several collagen fibrils combine to make up a tendon fiber (Figure 12.1). Bundles of fibers surrounded by connective tissue (endotenon) comprise a fascicle bundle. The endotenon surrounding the collagen fibers and fascicles carries blood vessels, nerve fibers, and lymphatics into the tendon. Loose connective tissue (epitenon) surrounds the whole tendon. In areas where tendons slide relative to adjacent tissues the tendon may also be enveloped by another loose connective tissue sheet called the paratenon. Together, the epitenon and paratenon is called the peritendon and these structures allow the tendon to glide with minimal resistance during movement.

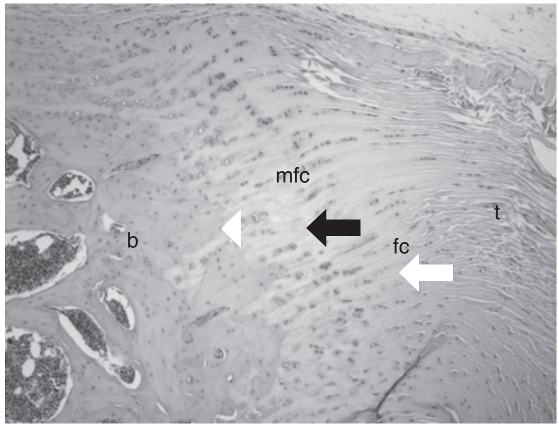

Figure 12.2. The area where the tendon inserts into bone the highly specialized "osteotendinous junction." There is a transition through four consecutive structural zones: the tendon zone (t), fibrocartilage (fc), mineralized fibrocartilage (mfc), and bone (b). Note the gradual transition from the tendon tissue to fibrocartilage; more rounded chrondocyte-like cells (white arrow) and type II collagen (black arrow) increase in prominence to make the tissue appear more "cartilage like." The fibrocartilage zone is terminated by a distinct border with the mineralized fibrocartilage zone (white arrowhead), this then intercalates with bone

The area where the tendon inserts into bone is the highly specialized "osteotendinous junction." Here, the viscoelastic tendinous tissue transfers force to the rigid bone, and there is a gradual change in the mechanical properties that is achieved by transition through four consecutive structural zones; the tendon zone, fibrocartilage, mineralized fibrocartilage, and bone. The transition from the tendon tissue to fibrocartilage is gradual; more rounded chrondocyte-like cells and type II collagen increase in prominence to make the tissue appear more "cartilage like." Moving even further toward bone, the fibrocartilage zone is terminated by a distinct border beyond which the mineralized fibrocartilage zone begins, this then intercalates with bone (Figure 12.2).

Tendon mechanics and strength

Normal tendons can sustain strain levels up to 20% before suffering initial failure (Figure 12.3). When testing human tendons in vivo, strain levels at maximal isometric muscle contractions have ranged 7–18% depending on the tendon investigated. However, the “single strain” condition is not the only way that tendons can be injured. In sportspeople, tendons are mostly subjected to repeated or prolonged loading. This can cause fatigue damage, even though each single loading is well below the maximal strength of the tendon—this is defined as fatigue damage.

Although a completely stiff structure would provide the most efficient force transduction from muscle to bone, tendons are quite elastic. Thus, when a tendon is loaded and elongated, tendon force is built up, and energy is stored within the tendon. This stored energy can be released from the tendon and utilized to create or prevent joint movement. This process conserves energy and improves efficiency of locomotion. It is estimated that the elastic energy contributes as much as 60% of the energy demand during locomotion. Although a thin and long tendon will assist energy storage and release, it may be more vulnerable to injury. A thicker tendon, which would yield less strain energy, would reduce the stress across the tendon and thereby provides the tendon with a greater safety margin. Thus, from an injury prevention standpoint a presumably healthy (physiological) hypertrophic tendon adaptation to exercise would be advantageous since it will reduce the amount of stress on the tendon.

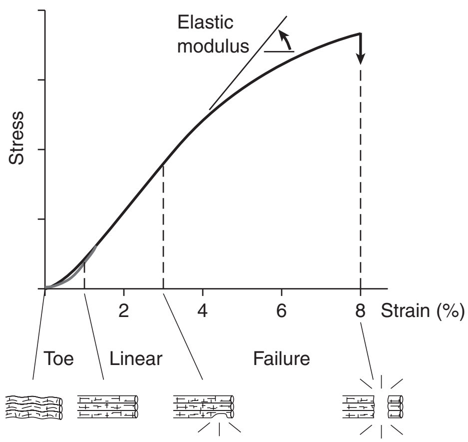

Figure 12.3. Stress strain curve. There is a “toe” region where strain can increase with little increase in stress. Then there is a “plastic” region where increased strain causes a linear increase in stress. The term “plastic” means the change is reversible. Beyond the plastic region is tendon failure—frank rupture of tendon tissue. The elastic modulus is a measure of how “stiff” a tendon is; the stiffer the tendon, the steeper the slope of the curve

Unquestionably, tendons are remarkably strong, a tendon with a cross-sectional area of 1 cm^2 (approximately corresponding to a normal adult patellar tendon) will be able to withstand a tensile load of 10,000 N or 1000 kg—perhaps 10–15 times body weight. The strength of tendons is related to the cross-sectional area (number and thickness of parallel fibrils) of the tendon and the tensile quality of the tendinous tissue (related to factors such as intrafibrillar cross-links and collagen type distribution). In other words, the greater the cross-sectional area, number of cross-links and type I collagen content of a given tendon, the greater loads can be withstood by the tendon before failure occurs if all other factors are equal. The tensile strength of a non-injured tendon is normally several times higher than the strength of its attached muscle leaving most tendons with a substantial tensile safety margin. However this may not be the case for all tendons during all circumstances. Patellar tendon forces have been estimated to be as high as 8000 N during landing and 9000 N during sprinting and tendon loads in the human Achilles tendon reach 9000 N during running. Thus, some tendons, including the patellar and especially the Achilles, may operate close to their maximal strength tolerance.

Tendon adaptation to loading

Mechanical loading stimulates collagen production dramatically—a single bout of exercise doubles the synthesis rate of collagen, and maintains this elevated level for 2–3 days. This increased synthesis is dose- or intensity-dependent. In short-term exercise, collagen degradation is also elevated, resulting in little overall gain in collagen production.

After several weeks of exercise stimulus, degradation returns to normal levels so that overall collagen synthesis is increased (Kjær, 2004).

These new findings indicate that tendon tissue responds much more dynamically to loading than previously thought and that intermittent loading could cause a negative balance between new collagen formation and collagen degradation. Also, the fact that matrix protein formation is already elevated after one acute bout of exercise and remains elevated for around 48 h after exercise indicates that from "a matrix point of view," it would be sufficient to train every other day to optimally stimulate matrix tissue of the tendon. Thus, the apparent mismatch between how quickly tissues such as skeletal and heart muscle adapt to loading, and how frequently such tissues tolerate the training stimulus, and the fact that connective tissue such as the tendon has a more "delayed" and slower adaptation pattern, may explain why tendon can be the weak link in situations of intense training or overloading.

Although physical training is associated with a chronic elevation of collagen turnover, it is not clear to what extent this leads to net collagen synthesis and tendon growth. Although trained men (but not trained women) have greater Achilles tendon cross-sectional area than their untrained counterparts, 9 months of running training did not increase the cross-sectional area of the Achilles tendon. As training strengthens tendon mechanically, it is likely that several factors other than just the amount of collagen in the tendon are important in the training-induced adaptation of healthy tendon in humans.

Some investigators have suggested that endurance training results in qualitative changes (improved tissue mechanics) but not quantitative (increased tendon size) changes, whereas other investigators have concluded that tendons react to endurance training by both quantitative and qualitative augmentations.

Tendon pathology

Tendon pathology induces dramatic changes in tendon structure, with changes in both the cells and the extracellular matrix that results in poorer mechanical properties and capacity to sustain load. The matrix changes are extensive and responsible for the fundamental decrease in load-bearing capacity of the tendon. Ground substance is increased and becomes more cartilage-like in composition, primarily seen in a change from small to large proteoglycans with more glycosaminoglycan chains. Collagen is disrupted, and altered in type from type I to smaller diameter fibers of type II, and III, and there is an increase in vascularity and neural ingrowth to the tendon (Figure 12.4). Overall, it seems that extracellular matrix homeostasis is important to maintain normal tendon function and that disruptions of the matrix balance is an early sign or mechanism in tendon injury development.

We still lack a biomarker in human tendon that can provide an early warning sign of emerging overloading of the tendon. Clinically, tendon pathology can be detected by abnormal imaging (ultrasound or MR) (Figure 12.5). However, the correlation between pain and abnormal imaging is poor; tendons with abnormal imaging are not always painful, likewise tendons that appear normal to imaging can be painful.

Mechanism of tendon overuse injury

Despite the high incidence and prevalence of tendinopathies the exact etiology remains elusive. It is, however, generally accepted that overuse injuries are related to repetitive tensile loading and strain of the tendon. Thus, a tendon overuse injury implies an injury in response to repeated strains above a certain threshold. The response is driven by cell detection of load that causes increased protein production in the cell. Eventually the injury will manifest itself by increased ground substance, fibril disorganization, neovascularization and potentially pain and swelling.

As mentioned earlier, sporting activities that utilize energy storage capacities of the tendon or forceful eccentric components may maximally challenge the tendon's fatigue resistance and reparative capacity especially if there is little recovery time between exercise sessions. With enough

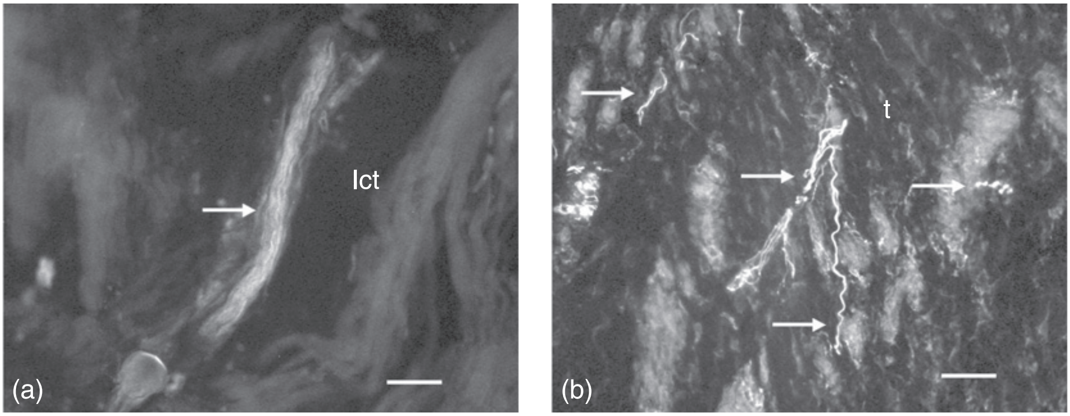

Figure 12.4. This photomicrograph compares neural tissue in (a) normal patellar tendon and (b) injured patellar tendon. In the side affected by chronic tendinopathy, there is increased spread and sprouting of nerve fibers (arrows) and they are not restricted to the loose connective tissue (lct) around the tendon. They invade the tendon itself (labeled a "t" in the image). Reproduced with permission from Øystein Lian, Johan Dahl, Paul W. Ackermann, Frede Frihagen, Lars Engebretsen, Roald Bahr. Pronociceptive and Antinociceptive Neuromediators in Patellar Tendinopathy. *American Journal of Medicine* **34**, 1801–1808 (2006). Published by Sage Publications.

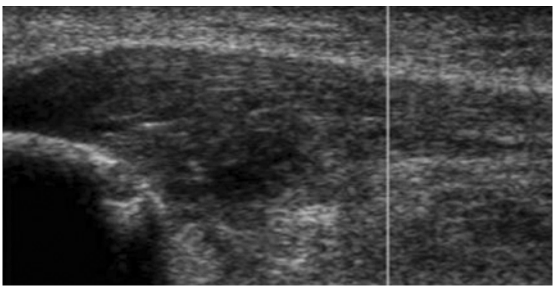

Figure 12.5. Tendon pathology can be detected as a hypoechoic appearance when the tendon is scanned using gray scale ultrasound

time between bouts of acute loading, tendons recover, but stress reapplied without sufficient recovery may lead to injury. This reminds us of the fine line between optimal loading for adaptation and loading that puts the tissue under too much reparative stress. It could be suggested that the tendon fibroblast increases protein synthesis in response to mechanical loading, but that this cannot increase further with higher-intensity exercise. This might explain why too much exercise (e.g., excessive jumping) can result in a suboptimal adaptation of the tendon and subsequent tendinopathy.

The development of tendinopathy may also be related to the structural properties of the tendons. Both the Achilles tendon and the patellar tendon have a non-uniform cross-sectional area distribution along their length and that the regions where tendinopathy most often occur in these tendons have the narrowest cross-sectional area. Thus, tendon overload injuries may arise at sites of stress concentrations (high force per area) in the tendons at these specific regions. However, it is unlikely that tendon stress is the sole factor in the etiology of tendinopathies. The majority of tendinopathies occur in the tendon closer to the attachment to bone. The tissue at the osteotendinous junction display inferior modulus and maximum stress compared to mid-tendon tissue.

Risk factors for tendon overuse injuries

Age

The prevalence of tendon pain and rupture increases with age, and this may be due to changes in tendon structure and mechanics. As tendons age they decrease protein content and increase cross-links, consequently the tendon is stiffer.

Tendons also thicken with age, and an increase in cross-sectional area may compensate for decreased "quality" of the tendon.

Younger tendons are also vulnerable to tendon pathology and in the adolescent population the prevalence of patellar tendon pathology in jumping athletes is similar to adults. At all ages, overload can produce pain in an already pathological tendon.

Sex

The prevalence of lower limb tendinopathy appears to be less in sporting women than among men with comparable training history, men have twice the risk of developing tendon pathology and pain compared to women (Lian et al., 2005). Possible reasons for this difference require investigation. Candidate hypotheses include that (i) men with larger muscles may be able to impose greater loads on their tendons, or subject them to more loading cycles, (ii) women's and men's tendons have different capacities to adapt to an increased or decreased loading, or, (iii) sex hormones may play a key role in tendon pathogenesis.

Genes

Researchers have unraveled the relationship between Achilles tendinopathy and genes for two proteins: tenascin-C and type V collagen. Certain types of genes (polymorphisms) in both the tenascin-C and collagen V genes were associated with Achilles tendinopathy and this association has been confirmed in a second population. Further research is ongoing, and if the link is clearly demonstrated, this may be the first demonstrated (non-modifiable) risk factor for tendinopathy. It is noteworthy that patients with a previous Achilles tendon rupture have a 200-fold risk of sustaining a contralateral rupture (Arøen et al., 2004). This strongly indicates either a genetic predisposition or other unknown predisposing factors in these individuals. Further evidence to support a strong genetic link is that the incidence of tendon ruptures in western countries far exceeds that in Africa and East Asia but at the same time it has convincingly been shown that Afro-American individuals have a substantially higher prevalence of tendon ruptures than matched Caucasian Americans (Owens et al., 2007).

Body composition

A recent cohort study has demonstrated that waist measurement was associated with patellar tendinopathy. This study reported that waist circumference in males of greater than 83 cm resulted in a 74% probability of morphological tendon abnormalities (via ultrasound), whereas males with waist of less than 83 cm had a 15% probability of tendon changes (Malliaras et al., 2007).

Body mass index has been associated with onset of tendinopathy. Nineteen out of 41 studies in a systematic review showed a significant association with adiposity and tendon health. In those having rotator cuff surgery there was a strong relationship between body mass index and risk of rotator cuff tendinopathy. A longitudinal study showed that the strongest predictor for developing upper limb tendinopathy was a body mass index of greater than 30. Further research is needed to identify the mechanisms for such associations, but like other musculoskeletal conditions it is likely that the mechanisms are more complex than just an increase in load on the tendon (Pottie et al., 2006).

Range of joint movement

A decreased range of ankle dorsiflexion range of movement is associated with both Achilles and patellar tendon pathology, and is likely to relate to increased tendon forces with landing. Interestingly, plantar fasciitis and Achilles tendinopathy have been also associated with an increased range of dorsiflexion.

Chronic disease

Glycation cross-links are increased in subjects with diabetes, making tendons stiffer and more prone to overload. Cross-linking is crucial in order to secure normal tendon function and tensile strength but increased cross-links and therefore stiffness, may be detrimental by reducing the strain to tissue failure. Spondyloarthropathy manifests as bone–tendon junction disease similar to athletic tendinopathy. These diseases have systemic and familial links, as does diabetes (especially type 1). In addition, type 2 diabetes is associated with increased abdominal adiposity, and interactions between risk factors for tendinopathy have not been clarified.

Muscle strength and flexibility

Muscle strength of the attached muscle has not been clearly shown to be a factor in the onset of tendon pathology. Athletes who can jump higher have more patellar tendon pathology in some studies (Lian et al., 2003), other studies do not support this (Malliaras & Cook, 2006). Reduced muscle flexibility has been shown to be associated with patellar tendinopathy, both the hamstrings and quadriceps have been implicated (Witvrouw et al., 2001).

Other factors

The amount of loading has been shown to be associated with patellar tendon pain and pathology. The type of flooring has also been implicated, a harder floor will increase tendon load (Ferretti et al., 1984).

Take-home message

Athletes who load heavily with training in sports and have a big energy storage and release component are vulnerable to tendon pathology. Each sport has its own collection of vulnerable tendons: the patellar tendon in jumping athletes, Achilles in running and court sports, and the adductor tendons in football players. This vulnerability is ameliorated or enhanced in individuals by intrinsic risk factors and a range of other unknown factors. Coaches are well aware that two athletes can train identically yet one will develop tendon pathology and pain and the other will remain symptom-free.

Although we can identify tendon pathology clinically with imaging, this does not allow us to predict which athletes will develop pain, and of these, which will develop pain sufficient to stop participation. At best, imaging might allow the coach or medical practitioner to be aware of which athletes are at risk (Fredberg et al., 2007), plan training so overload is minimal, and monitor and modify tendon load as necessary. Although this is far from satisfactory, tendon pain and pathology remain outside the injuries that can be easily controlled.

Preventing tendon overuse injuries

Because tendon pathology appears to result from an interaction between several individual and environmental risk factors, prevention is not merely a matter of following a single recipe for all athletes. A tendon that is not overloaded will not develop tendinopathy—it appears that repeated stretch-shortening cycles with body weight over time are required to generate tendon pathology and pain. However, as individuals appear to have a wide variation in load tolerance, it is not currently possible to provide "research evidence" for a narrow, defined load that minimizes risk of tendon overuse injury.

Adaptation to loading

The ability of tendinous tissue to respond to mechanical loading of the muscle–tendon unit is of great interest as inadequate adaptations may promote the development of injury and an adequate adaptation may reduce the risk of tendinopathy despite substantial tendon loading.

Tendinous tissue has traditionally been regarded as rather sluggish and static with a limited ability to react and adapt to exercise and training. However research has shown that tendinous tissue is highly capable of adjusting its metabolism to match an increase in loading and that the tissue can adapt to training. Interestingly, also in tendinopathic tendons, regular exercise does result in an upregulation of collagen synthesis, indicating that even in a diseased state, tendons benefit from a certain degree of controlled loading (Langberg et al., 2007).

Specific types of exercise: high intensity and strength training

There has been very little investigation of tendon responses and adaptations to intermittent high loads as those seen in jumping, sprinting and heavy strength training. Patellar tendon hypertrophy occurs in response to 12 weeks of heavy resistance training the increase in cross-sectional area occurred at the proximal and distal ends but not at the mid-tendon (Kongsgaard et al., 2007). This is supported by a study that showed high-resistance training reduced tendon pain (Frohm et al., 2007).

Specific types of exercise: eccentric training

Eccentric exercise places high load on tendon and it has been used extensively to rehabilitate painful tendons (Kingma et al., 2007). Its use as a prevention has been investigated only recently and a study of soccer players has shown that it did not reduce the risk of injury. In fact those with patellar tendon pathology at the beginning of the season were more likely to be injured if they did the preventative eccentric exercise (Fredberg et al., 2007). In a similar study in volleyball players, eccentric training in season did not improve tendon pain (Visnes et al., 2005).

Stretching

Stretching is used to prevent injury, in tendons the type of stretching may be critical. Dynamic stretching may be superior to static stretching as it alters the mechanical properties of the tendons (Witvrouw et al., 2007), whereas static stretching in many tendinopathies will increase the compressive load, known to cause pathological alterations in tendons. In athletes although static stretching may be relevant for the muscle, the best tendon response is to dynamic stretching.

Adjusting training load

Although overload has been clearly linked to tendon pain and pathology, athletes have widely ranging load tolerance. Thus, we are unable to prescribe simple protocols for adjusting load. However, energy storage and release causes tendon pathology, hence it is easy to say if you cycle or swim you are unlikely to get a tensional tendon overload (swimmers may get compressive overload of the rotator cuff). Outside of this recommendation, load management becomes more difficult, frequency of load appears important; training more than once in every 2 days does not allow the tendon to respond fully to each load stimulus. Nothing is known about modifying volume and intensity of load. A recent study that investigated gradual introduction of running compared to a standard running training program did not find any difference in injury between groups, because of individual variations in injury susceptibility very large numbers in such studies may be needed to clearly show if a difference exists (Buist et al., 2008).

Take-home message

Because tendon's response to different kinds of exercise and loading varies, coaches cannot follow "one-size fits all" approach. Tendons possess adaptational capabilities and in most circumstances will adapt adequately to different levels of exercise if they are given enough time. However, as tendinous tissue is somewhat slower to adapt than muscle tissue it is suggested that sudden increases or changes in exercise loads and modes should be avoided wherever possible. It would appear prudent for training changes to be prescribed cautiously to allow the tendon enough time to adapt and recover and prevent the development of injury. Abdominal fat, lack of fitness, and certain biomechanical factors are risk factors for overuse tendinopathy so these should be addressed in active individuals. Imaging (including ultrasound and MR imaging) does not appear to contribute to the clinical approach to tendinopathy prevention at this stage.

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Chapter 13
Implementing large-scale injury prevention programs

Randall W. Dick[1], Claude Goulet[2] and Simon Gianotti[3]

[1]Research/Injury Surveillance System National Collegiate Athletic Association, Indianapolis, Indiana, USA
[2]Department of Physical Education, Laval University, Québec, Canada
[3]Sport and Road Injury Prevention, Accident Compensation Corporation, Institute of Sport and Recreation Research New Zealand, Faculty of Health and Environmental Science, Auckland University of Technology, New Zealand

Introduction

It is well documented that regular sport participation or physical activity can improve health and quality of life. Moreover, in combination with a proper diet and a healthy lifestyle, physical activity is an influential factor in the control of body weight. From a public health perspective, the benefits of physical activity are clear.

There is, however, a cost of physical activity—namely the burden of injuries. Injuries resulting from sports and recreational activities are a significant health problem in many countries. There is now irrefutable evidence that the sports injury problem is not restricted to professional sports. For more than two decades, about every fifth unintentional injury treated in a health care setting in industrialized countries has been associated with sports or physical activity. This makes sport and recreational activity injuries probably the most ironic injury type. On one side, public health authorities are actively promoting regular sport and physical activity participation. On the other hand, it is known that if not practiced in safe environments, sport and recreational activity injuries could significantly reduce the public health benefits of regular sport and physical activity participation. In a public health perspective, it supports the importance of implementing large-scale injury prevention programs.

Implementing large-scale injury prevention programs poses many challenges. Drawing mainly from our experience and from published literature in the fields of sport and recreational activity injury prevention (see Chapter 2), we have produced a list of five key elements to consider in the development and implementation of large-scale prevention programs. These key elements are as follows.

Approach the injury problem at hand with a multi-dimensional view

It is essential to analyze any injury problem through a systematic approach and a multi-dimensional view (see Chapter 2). It maximizes the probability that all possible solutions to the problem will be addressed. Based on some of the latest conceptual advances made in the field of injury prevention, we also suggest that the following guiding principles be considered in the analysis process: (1) Consider the cost/benefit ratio when selecting an intervention strategy; (2) consider the impact an intervention might have on the nature of the sport; (3) choose interventions adapted to the problem at hand: either inform, convince, or contrive (see Section “Active versus passive measures” in Chapter 2); and (4) Encourage partnership.

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Beliefs confuse the issue; get the facts

Sport is an area where changes occur slowly because of deep-rooted beliefs. You need well-documented facts on the injury problem as well as the effects of the proposed measures before trying to convince the targeted group—whether it be elite athletes, recreational participants or owners of sport facilities.

Work toward a consensus; develop coalitions

Even if you are in a position to impose mandatory safety measures, make sure you develop strong grass-roots support for your intervention. As a sport injury prevention specialist, identify the key stakeholders and work with them on solutions that they are willing to apply. Be prepared to support these partners with information and training.

Recognize the limits of information campaigns; develop back-up technological systems

Public awareness campaigns are important, but they are not enough. Well-informed people are still human beings; which means that knowledge does not necessarily result in behavior change. One of the most efficient ways to improve sports safety is through the modification of the environment (see Section "Active versus passive measures" in Chapter 2).

Try to change the perception that more safety brings less fun

Safety is often perceived as something that will take fun away from sport and recreational activities. In fact, safety measures can allow participants more enjoyment from their activity by giving them "peace of mind." In general, outdoor specialists understand this positive side of safety. Safety is often what makes their activity possible. We can all learn from their attitude toward safety skip line after end of PP.

The aim of this chapter is to present five practical examples of large-scale programs that have been implemented by the National Collegiate Athletic Association (NCAA) in the United States of America, by the Accident Compensation Corporation (ACC) in New Zealand, and by the provincial government in the Canadian province of Québec. Each example will incorporate the five key elements previously discussed within the context of the four step injury prevention model (IPM): (1) describing the magnitude of the injury problem, (2) understanding the causes, (3) introducing measures likely to reduce the future risk and/or severity of injuries, and (4) evaluating their effect (Figure 2.1). These examples and approaches should help key stakeholders in sports injury prevention to implement efficient large-scale injury prevention programs to improve the social and health benefits of sport participation.

The American National Collegiate Athletic Association model

The NCAA is an organization of approximately 1100 colleges and universities established in 1906 to govern athletics competition in a fair, safe, equitable, and sportsmanlike manner and to integrate intercollegiate athletics into higher education. The association conducts its business through a committee structure made up of diverse representatives from member institutions. Nationally, more than 380,000 student–athletes participate in NCAA sports that offer national championships.

Recognizing its organizational health and safety roots, the NCAA has maintained an Injury Surveillance System (ISS) for intercollegiate athletics since 1982. The primary goal of the system is to collect injury and exposure data from a representative sample of NCAA institutions in a variety of sports. Relevant data are then shared with appropriate NCAA sport and policy committees to provide a foundation for evidence-based decision-making on health and safety issues. The NCAA model of a sport organization with (1) a committee structure with the authority to develop enforce policy, (2) data collections systems such as the ISS to provide an information foundation for decision-making, and (3) a review process to assess policy effectiveness has been beneficial in a variety of injury prevention initiatives.

Example 1: Wrestling with weight loss—The NCAA Wrestling Weight Management Program

The problem (IPM Steps 1 and 2)

In a span of 33 days in late 1997, three collegiate wrestlers died while engaging in a program of rapid weight loss. All were in the presence of coaches.

According to the Centers for Disease Control and Prevention's (CDC, 1998) review of the cases, the wrestlers were attempting to lose an average of 8 pounds over a 3- to 12-h period by wearing rubber suits and exercising vigorously in hot environments. The wrestlers were attempting to lose this weight AFTER dropping an average 21 pounds over the previous 2–3 months.

There were no previous recorded deaths in NCAA wrestling associated with making weight but the sport in general had a reputation for rapid and severe weight fluctuations similar to those reported in these three cases.

Understanding the facts and the belief structure (IPM Steps 1 and 2)

The sport of wrestling had a variety of issues to consider before addressing the problem.

1. Established guidelines: Position statements associated with weight loss in wrestling from organizations such as the American College of Sports Medicine (ACSM, 1996) had existed for many years. The three deaths brought attention to weight loss behaviors that, in some cases, had been contrary to medical guidelines for many years.

2. Safety: The NCAA ISS had shown wrestling as a sport at very high risk for injury relative to other sports monitored by the system (Agel et al., 2007). Many of the injuries may have been directly or indirectly associated with improper weight loss practices or their after-effects.

3. Competitive equity: Weight was acknowledged to be the competitive equity variable in the sport of wrestling. Weight classes were established to assure that opponents were paired against athletes of similar weight. Prior to these fatalities, collegiate wrestlers were able to make weight at least 24 h prior to competition, When the actual competition took place, both opponents generally weighed significantly more than the designated weight class they had qualified for the previous day (mean 3.3 kg in one study;Horswill et al., 1994). There also could be a significant weight differential between the two individuals (mean 1.5 kg in one study; Scott et al., 1994) nullifying any competitive equity associated with weight class.

4. Wrestler mindset: Wrestlers believed that self-discipline, commitment and sacrifice they learned from making weight would help make them better wrestlers. Cutting 3–7% body weight and then regaining it the next day was perceived to allow one to gain a strength and size advantage over a "smaller/weaker" opponent.

Working toward consensus: identifying the stakeholders

In the aftermath of the wrestling deaths, the NCAA joined with other organizations to create a joint resolution which said, in part: "Eliminate from wrestling any and all weight control practices which could potentially risk the health of the participants."

Two NCAA committees, the National Wrestling Coaches Association, USA Wrestling, the national governing body for wrestling and various medical organizations were involved in the discussions. Coaches, student-athletes, exercise physiologists, athletic trainers, physicians, athletic administrators, sport governing body officials, and lawyers were all represented. Since weight cutting mostly occurred in the practice environment, and could not be regulated effectively by competition rules, the wrestling coach was identified as a key stakeholder. While certain policies could be implemented and enforced, the wrestling coach, and his or her attitude toward weight cutting leading up to competitions, ultimately would determine the success of the program.

NCAA weight management program components (IPM Step 3)

The NCAA weight management program (Figure 13.1) was based on four guiding principles:

- Enhance safety and competitive equity
- Minimize incentives for rapid weight loss

Figure 13.1. The NCAA Wrestling Weight Management Program shows promise for increased safety and competitive equity for wrestling participants of all ages

- Emphasize competition, not weight control
- Implement practical, effective, and enforceable guidelines.

Specific components included: establishing weight classes that better reflect the collegiate wrestling population, establishing a permanent healthy weight class (lean body weight plus at least 5% body fat) early in the season with time to achieve it safely, establishing weigh-ins as close to the match as possible, eliminating the tools used to accomplish rapid dehydration, and requiring CPR certification of all wrestling coaches.

Evaluation of the weight management program (IPM Step 4)

To evaluate effectiveness, research investigating the changes in weight and body composition relative to performance over the course of the season was initiated. Research conducted over the entire wrestling season showed that the most successful wrestlers chose to participate at a body composition well above the minimum allowable value of 5% and that reducing the time between weigh-ins and competition was effective in reducing rapid weight loss. A weight management program coupled with reducing time between weigh-ins and competition was even more effective.

Discussion

The successful NCAA model includes injury surveillance (facts), input from diverse constituents (consensus), a committee structure with the capability to enact and enforce formal policy, and specific research to determine policy effectiveness. The NCAA wrestling weight management program has become a model program for the sport and has been accepted by collegiate wrestlers and coaches. The sport has become more fun for participants as the emphasis has switched from weight loss to skill development. In the 2004–2005 academic year, this program involved 224 intercollegiate wrestling programs, touching almost 6000 student-athletes. In 2006 the National Federation of State High School Associations (NFHS) implemented a similar weight management program at the United States high school level impacting over 250,000 student-athletes. These programs show promise for increased safety and competitive equity for wrestling participants of all ages. A similar weight management program may be beneficial at higher levels of wrestling and in other Olympic weight category sports such as rowing and boxing.

The New Zealand model

In New Zealand, determining the size and scope of a particular sport injury problem is relatively simple. This is largely due to the existence of a mandatory no-fault 24-h injury scheme providing coverage for injury treatment and rehabilitation costs. The scheme is administered by the Accident Compensation Corporation (ACC). In the last ACC financial year (1 July 2006 to 20 June 2007—2006/2007), the 4.1 million New Zealanders made 422,000 sport and recreation claims, costing the Corporation $NZ 329 million. There is no disincentive for making a claim; people are not discriminated, risk rated or penalized for the number of claims they make. The cost of claims and the legislation governing the ACC provides incentive for investing in large-scale injury prevention programs. ACC has a cost-outcome model to determine investment levels and programs are expected to provide a return on the investment. ACC currently targets moderate to serious injury claims for its sport cost-outcome model. Although moderate to serious injury claims may make up only a small proportion of all sport claims, 7.4% in 2006/2007, they represent around 75% of the cost.

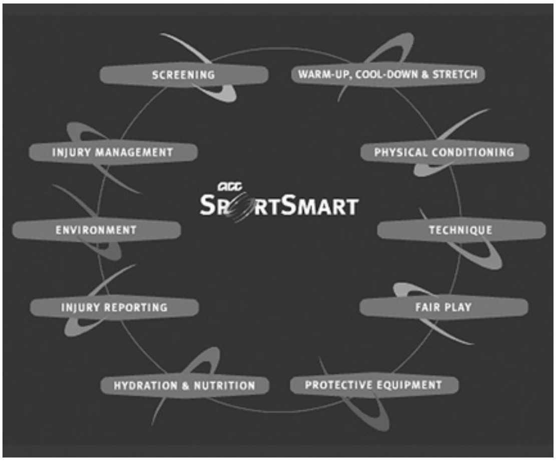

Figure 13.2. The New Zealand Accident Compensation Corporation SportSmart model is a 10-point action plan for sports injury prevention

In 1999, ACC developed the SportSmart model, a 10-point action plan (screening, warm up/cool down, physical conditioning, technique, fair play, protective equipment, hydration/nutrition, injury reporting, environment, injury management) (Figure 13.2) for sports injury prevention and has since developed a range of sport-specific injury prevention programs based on this model. This initiative relies on a coalition between ACC and the respective national sporting body. Two specific applications of the SportSmart model are discussed in the following section.

Example 2: The RugbySmart Program—preventing injuries in rugby union

The injury problem (Steps 1 and 2)

Rugby Union (rugby) represents the largest percentage (15%) of sport moderate to serious injury claims to ACC. It is also a sport that has been associated with serious spinal injuries. Due to their severity and life changing impact, these injuries draw media attention and focus on to rugby.

In 1996, the New Zealand Rugby Union (NZRU) implemented a compulsory safety course for coaches and referees, with the focus on preventing serious spinal injuries. Analysis of the compulsory safety course showed that it was not achieving the desired effect, despite early reported results. In 2000, ACC and NZRU formed a coalition to tackle the injuries. ACC data identified neck/back/spine, shoulder, knee, ankle, and leg (excluding knee and ankle) injuries to target in addition to serious spinal injuries. These body parts were predominantly injured in contact situations of the scrum, tackle, ruck, and maul phases of the game. Improving technique in these phases lowers the risk of injury and moderate to serious injury claims. The program targeted community-level (non-professional) 15–44-year-old rugby players due to their impact on the ACC scheme; they represented 34% of the players, but 92% of the rugby moderate to serious injury claim costs.

Understanding the facts and belief structure

While there was acknowledgment that the incidence of serious spinal injuries needed attention, the NZRU compulsory safety course was widely viewed as undesirable and was not well received by the rugby community. Common reasons included:

1. Coaches/referees were volunteers and were difficult to recruit; having to undertake a compulsory safety course was yet another commitment on the coaches time.

2. The focus was on the consequences of a serious injury. Highlighting the problem had the potential to turn people away from coaching/refereeing.

3. Coaches perceived that they knew most of the information imparted in the compulsory course and that it was the same every year.

In summary, a system to deliver compulsory safety education was in place but it needed to be made more suitable to the audience to achieve buy-in and acceptance.

Working toward consensus: identifying the stakeholders

By developing a coalition, both groups could achieve appropriate outcomes. ACC desired a reduction in the number of injuries, as it provided for the cost of rehabilitation and replacement of earnings, whereas the NZRU wanted to make the game a competitive, safe, and popular sport.

The new program, RugbySmart, was developed based on SportSmart and implemented in the 2001 rugby season with ACC investment. The NZRU compulsory safety course evolved to RugbySmart and was repackaged to focus more on causes of injury rather than consequences. In addition to NZRU and Rugby Development Officers, coaches and referees also were identified as stakeholders. RugbySmart targeted coaches and referees as (i) reaching 137,000 players via coaches/referees was more effective than targeting each player directly and more effective than relying on clubs and schools and (ii) coaches were identified by both players (and coaches) as having an important role in injury prevention.

The RugbySmart program (Step 3)

RugbySmart involves the screening of a DVD at a compulsory workshop, as originally put in place by NZRU. The DVD contained aspects of the 10-point action plan, with an emphasis on areas where injury issues have been identified, such as the scrum, tackle, and ruck (Figure 13.3). The workshop was conducted by Rugby Development Officers (for coaches) and Referee Education Officers (for referees), and these positions were funded by NZRU.

Figure 13.3. The RugbySmart DVD used in the workshops is a key factor in implementing injury prevention in rugby that has resulted in decreases in serious spinal injuries and injury claims in targeted injury areas

Having a DVD ensured consistency of delivery and supported the facilitator. RugbySmart, like its NZRU predecessor was compulsory for coaches and referees to attend. Team were withdrawn from competition and referees were not assigned games if they did not attend. While the compulsory education aspect was appealing to ACC and ensured a captive audience, it also created resistance to the program. This was largely overcome by developing a product that appealed to the coaches and referees. For example, promoting correct or winning technique as safe and then demonstrating skills that focused on the improved technique was a successful strategy. The skills demonstrated were in a straightforward manner, allowing coaches to master them and easily incorporate into trainings.

Evaluation of the RugbySmart program (Step 4)

RugbySmart was evaluated in several ways and the results were used to develop the program further, keeping it fresh and relevant. NZRU is one of the few sports in NZ to have an accurate and reliable player registration system, providing a moderate to serious injury claims rate per 100,000 players to determine the effectiveness of RugbySmart. Evaluation justified continued investment in the existing program as well as in further areas that warrant investigation. The return on the investment was $7:78 for every ACC $1 invested (Gianotti & Hume, 2007). The results of the RugbySmart program showed a decrease in serious spinal injuries in the scrum (Quarrie et al., 2007), decreases per 100,000 players in moderate to serious injury claims in targeted injury areas (Gianotti et al., 2008), and increases in desired training behaviors in safe scrum, ruck, and tackle at practices/trainings (Gianotti et al., 2008).

Example 3: The SoccerSmart Program—preventing injuries in football (soccer)

The injury problem (Steps 1 and 2)

Based on the initial success of RugbySmart, ACC was keen to implement SportSmart into other sports. Football was targeted as it represented the second largest percentage of sport claims (7.2%) to ACC. While ACC and New Zealand Football (NZF) had previously developed some injury prevention initiatives, they were small and involved using the generic SportSmart model rather than a football-specific one. Attention was also focussed on secondary/tertiary prevention (e.g., training for the treatment of soft-tissue injuries).

The ACC system could, like in rugby, pinpoint the type and nature of football injuries. Initially the focus was all moderate to serious soccer injury claims. However, in 2005 the system targeted players aged 15–44 years who represent the greatest percentage of football moderate to serious injury claims (85%) with knees (38%) and ankles (19%) being the most predominate injury sites. To address these injuries, the SportSmart model was adapted for football to provide relevance to the target group. Feedback from initial projects with NZF had highlighted the need for this specificity. In addition, the world governing body for football FIFA's Medical and Research Committee (F-MARC) had developed a program called "The 11" which ACC were keen to see implemented.

Understanding the facts and belief structure

While there was success with the RugbySmart concept, football required a completely different approach to build a coalition due to the following:

1. Financial considerations: Rugby has an annual budget 10–50 times that of other sports with the same playing numbers. Investing in the community aspect of the game on this scale was difficult to repeat in other sports. NZF has fewer staff and could not afford to devote the time necessary to develop and implement an injury prevention program.

2. Non-governed participation: There are different forms of football that NZF does not control. ACC data collection did not distinguish between forms of football (e.g., indoor soccer, 6-a-side, 11-a-side), as it is a no-fault system. This impacted on the ability to undertake evaluations.

3. Inaccurate playing numbers: NZF does not keep accurate playing numbers and relies on estimates. This is a further hindrance to evaluation and also limits the development of a cost-outcome model to help secure ACC investment.

4. Public perceptions. Football is considered a safer sport than rugby. It does not produce serious spinal injuries and parents have been known to remove their children from rugby in favor of football due to injury risk perception.

Working toward consensus: identifying the stakeholders

To encourage an increased emphasis on injury prevention and to engage NZF, ACC increased its investment in the sport. This provided for NZF to employ a person whose primary responsibility would be injury prevention, but who would also be available for other NZF duties. Having a person essentially inside NZF devoted to injury prevention gave this topic credibility and emphasis in the sport. This was essential in developing a coalition with NZF. The remaining ACC investment was for injury prevention resources, ensuring the injury prevention person had an established and targeted budget rather than bidding and competing for existing NZF funds. While ACC was prepared to make this investment, it still took NZF 18 months to formally agree to a coalition. This was more reflective of a busy sport rather than a reluctance to be involved in injury prevention. Key discussion points included compulsory training of coaches and rule changes. NZF was not in the same position as NZRU to make injury prevention training compulsory for coaches and the sport also was concerned about the expectation to implement rule changes and the subsequent implications.

The SoccerSmart program (Step 3)

In 2004, NZF (formally New Zealand Soccer) and ACC adapted SportSmart to create SoccerSmart. Despite the governing bodies name change, from soccer to football, the SoccerSmart brand was retained because of its market recognition. Football coaches were identified as a suitable initial target and SoccerSmart was included in all existing NZF coach education courses, as well as a stand-alone workshop. Resources were created to be included in each course pack. These included booklets, wallet

Figure 13.4. The SoccerSmart resources targeting has shown a claims reduction against forecast for knee and ankle injuries in 15–44-year-old soccer players

cards (pocket-sized folded information sheets), and posters that addressed all 10 SoccerSmart action points. Resources were designed to be used by coaches and passed on to players. FIFA's "The 11" resources were also included in the SoccerSmart course packs (Figure 13.4). SoccerSmart (similar to RugbySmart) focused on injuries or injury-related issues that were more prevalent in the sport of football, as determined from the ACC claims database. These included tackling, physical fitness, and prematch issues. Special care was also taken with the language and phrases used in SoccerSmart, to ensure suitability for the audience.

Evaluation of SoccerSmart program (Step 4)

As with all injury prevention ACC invests in, moderate to serious injury claims are used for evaluation. Unlike Rugby, NZF could not provide accurate playing numbers, nor an accurate estimate of the prevalence of indoor soccer. As such, moderate to serious injury claims were assessed against a forecast, made by ACC, as part of its cost-outcome approach (see Further reading). In 2006/2007, the return on the investment for all soccer moderate to serious injury claims was $2.41 (Gianotti & Hume, 2007) and there was 2.5% fewer claims against forecast for 15–44 year olds in knees and ankles. This resulted in ongoing investment in the SoccerSmart program. However, the actual number of football moderate to serious injury claims is increasing, which is purported to be due to the anecdotal reports of marked growth of the game. Hence a forecast is used on the absolute number of moderate to serious injury claims.

Discussion

The NZ examples show a passive model that can be adapted to other sports and is effective in achieving injury prevention outcomes. In these examples, education plays more of a role than enforcement and engineering of the injury prevention matrix (see chapter 2) since there is no ability to enforce rules or make a sport undertake injury prevention by withholding injury coverage. A strong coalition with the national body (NZRU, NZF) is crucial for the implementation of an effective sports injury prevention program. While investment and funding is also important, this investment would not have been as effective if the national bodies were not supportive. This is particularly important for large-scale implementation of injury prevention programs.

The Canadian Province of Québec model

Injuries resulting from sports and recreational activities are a significant health problem in Québec. The Canadian Community Health Survey of Statistics Canada revealed that in 2003 in Québec, injuries which occurred in a sport and leisure venue represented 21% of all injuries resulting in limitation of normal activities or medical consultation, compared with 35% of injuries at home, and 8% on the road. Moreover, participation in sport and recreational activities was the leading cause of non-intentional injuries in Québec in 2003 (25%), before occupational injuries (23%). Of course, sport and recreational activity injuries are not all severe: there are more deaths on Québec roads than on sports fields and, generally, road injuries are more severe. However, the public health burden of sport and recreational activity injuries is manifest in their morbidity. A population-based survey done for the Québec Ministry of Education, Leisure, and Sport estimates that during the year 2004, 514,000

Québec residents aged between 6 and 74 years consulted a health professional to treat a sport and recreational activity injury (88/1000 participants). These data clearly show the scale of the sport and recreational activity injuries problem and the importance of establishing safe environments.

In 1979, to significantly contribute to the establishment of safe environments, the government of Québec adopted the *Act Respecting Safety in Sports* which created the Québec Sports Safety Board (Régnier & Goulet, 1995; Government of Québec, 1988). Since 1998, through its mission to "foster the development of recreation and sport in a safe and healthy environment and promote an active lifestyle for all Québecers," the Safety Promotion Unit of the Québec Ministry of Education, Leisure, and Sport supervised the execution of the *Act Respecting Safety in Sports*. In accordance with this act, one of the Safety Promotion Unit's orientations is to "ensure that the safety and physical security and well-being of participants are provided for during sports and recreation activities."

With respect to the *Act*, the Safety Promotion Unit is empowered to

1. Gather, analyze, and disseminate information on sports safety.

2. Conduct, or cause others to conduct, research on sports safety.

3. Educate the public on safety in relation to the practice of sports.

4. Prepare safety training methods for persons who work in the sports field.

5. Give technical assistance to sports federations or unaffiliated sports bodies in preparing safety regulations.

6. Assist any person requesting advice on means to ensure sports safety.

Two examples of the application of the Québec Model are presented in the following example.

Example 4: Bodychecking injuries in minor ice hockey

The injury problem (Steps 1 and 2)

Ice hockey is one of Canada's most popular winter sports, with more than 500,000 registered players in the Canadian Hockey Association. In 2004–2005, it was estimated that 9%–31% of all Canadian boys participated in organized leagues.

In the 1970s, faced with an increase in ice hockey violence and poor performances at the international level, Canadian administrators and other individuals involved with North American hockey began to question their basic philosophies of the game. This awareness sparked increased research in ice hockey which was followed, in some cases, by changes in the rules, particularly at the minor level. One of the major changes was the abolition of bodychecking for players 12 years old and under. Bodychecking is defined as an individual defensive tactic designed to legally separate the puck carrier from the puck by use of physical contact.

In 1985, to allow Midget age players (15–16 years old) who wanted to play junior hockey to finish high school in their home towns, the Canadian Hockey Association decided to raise all age groups by 1 year, thus making the Pee Wee category 12–13 years old. With those age changes, the "no bodychecking" rule was reconsidered. After a brief discussion during their general meeting of 1985, the Canadian Hockey Association adopted a new rule allowing bodychecking for Pee Wee category.

In the province of Québec, faced with a controversy on the risk of injuries associated with the new rule, Hockey Québec (the Québec Ice Hockey Federation) asked the Québec Sports Safety Board for its opinion on the matter.

Understanding the facts and belief structure

Realizing that no hard scientific data were available on the effect of bodychecking on the safety of Pee Wee players, the Québec Sports Safety Board sponsored an appropriate research study (Régnier et al., 1989). Consistent with the first key element mentioned earlier, the multidisciplinary nature of the research group allowed its members to study the following topics:

1. The attitudes and beliefs of coaches, parents, and players toward bodychecking.

2. The morphological and biomedical differences among Pee Wee players.

3. The number and types of penalties within leagues playing with and without bodychecking.
4. The injury rate among Pee Wee leagues playing with and without bodychecking.
5. The modeling effect of professional hockey.
6. The training of coaches in the teaching of bodychecking.
7. The effects on participation.

The most influential study result relative to public awareness was that Pee Wee players were 12 times more likely to suffer a fracture in leagues that allowed players to bodycheck. The rate of fracture was 1 per 22 games in leagues where bodychecking was allowed compared to 1 per 263 games in leagues where bodychecking was not allowed. The weight and height difference between players was shown to be one of the most important risk factors of injury. Morphologic and strength differences between the smallest and the largest players competing at the Pee Wee level revealed an average weight and height difference of 37.2 kg and 31.5 cm, respectively. Furthermore, a 70% difference in the force of impact during bodychecking between a group of small players and larger players was observed.

Working toward consensus: identifying the stakeholders

With those results, the next step was to convince the minor ice hockey administrators to ban bodychecking at Pee Wee level. Some factors had major influence. The involvement of a well-respected team of university researchers in the study was important, bringing credibility to the process. Moreover, the public health network of the province highly supported the actions to ban bodychecking at Pee Wee level and information campaigns in the media were launched to influence public awareness. Finally, the Minister responsible for the administration of the *Act Respecting Safety in Sports* was lobbied for his support of the proposal.

The preventive measure (Step 3)

Based on those results, Hockey Québec decided to ban bodychecking for all Pee Wee leagues in Québec (Robidoux & Trudel, 2006). Today, Québec is the only province or territory where bodychecking is still banned for this age group. In the other provinces, there is still controversy about the issue. Government reports and academic studies have identified some problems related to bodychecking and further educational initiatives have been launched. For example, the Canadian Hockey Association has been actively providing courses on the appropriate bodychecking techniques for coaches, players, managers, referees, trainers, and parents. Only a few training initiatives have been evaluated and the overall effectiveness of these courses on injury prevention has not been established.

Evaluation (Step 4)

It is estimated that in 20 years, this large-scale measure prevented 4000 young growing players to suffer from a fracture. Moreover, there is no evidence that the ban of bodychecking at Pee Wee level reduced the level of competitiveness of Québec players at national or international levels of competition.

Example 5: Full–face protection to prevent facial injuries for adult ice hockey players

The injury problem (Steps 1 and 2)

Even if ice hockey is one of the leading contributors to sports-related injuries in Québec, it provides the sport and public health communities with an impressive success story of injury prevention: the quasi-elimination of eye and facial injuries through the use of face protectors.

In the mid-1970s, Canadian and US ophthalmologists documented a significant incidence of serious eye injuries in ice hockey players. This public awareness brought together safety specialists, amateur ice hockey governing bodies, and sport equipment manufacturers in an attempt to improve available eye and face protective equipment and to increase its routine use in the sport.

These efforts led to the adoption of a Canadian and a US standard on face protectors for ice hockey players. The standards led in turn to the adoption of regulations imposing the use of a certified full-face protector for all minor league players (18 years or under) in the United States starting with the 1976 season, and in Canada starting with the 1978 season. However, the large population of adult hockey players remained at risk because full face protection was not required beyond age 18.

Understanding the facts and belief structure

The effect of the use of certified full-face protectors by minor league players have been well documented in Canada and in the United States of America. For instance, no eye injuries have been recorded for a player wearing a full-face protector certified by the Canadian Standard Association. But the most eloquent demonstration of the effectiveness of full-face protectors was based on reports from Canadian ophthalmologists. In 1974–1975 the average age of hockey players suffering from an eye injury in Canada was 14 years. In 1983–1984, 5 years after full-face protectors were imposed on all minor league players by the Canadian Hockey Association, the average age of the victims rose to 24 years (Pashby, 1985). From these results, it was determined that the main population at risk of eye injury in hockey had become the thousands of adult recreational hockey players participating in organized leagues not subject to the Canadian Hockey Association regulation.

Many studies conducted in Québec between 1982 and 1987 confirmed these conclusions as to the vulnerability of 90,000 adult recreational players not wearing full facial protection. Observations in a representative sample of arenas in Québec revealed that only 25% of these players wore facial protection in 1987 in spite of previous social marketing campaigns promoting the voluntary use of full-face protectors. A major challenge was introducing a new piece of equipment to a generation that had not grown up with it.

It was clear that the use of full-face protectors by adult ice hockey players needed to increase by enacting regulation requiring their use. But, before the implementation of such regulation it was important to convince the players to comply with the regulation.

Figure 13.5. Mandating full-face protection in adult league Québec ice hockey players has shown a dramatic decrease in eye injuries and a positive promotional cost/health care savings ratio

Working toward consensus: identifying the stakeholders

As was the case for the ban of bodychecking at Pee Wee level (Example 4), the regulation imposing the use of full-face protectors by adult ice hockey players was supported by the public health network of the province, and by groups of ophthalmologists in Canada and in the United States of America. This support significantly enhanced the credibility of the regulation. Social marketing campaigns promoting the use of full-face protectors were also undertaken (Figure 13.5). The Minister responsible for the administration of the *Act Respecting Safety in Sports* also had to be convinced.

The preventive measure (Step 3)

To significantly reduce the incidence of eyeinjuries to adult ice hockey players, the Québec Sports Safety Board enacted a regulation imposing full-face protectors on all adult ice hockey players participating in an organized league.

The evaluation (Step 4)

The regulation imposing full-face protector had an immediate and long-lasting effect on the use rate of full-face protectors among adult recreational hockey players in Québec. One year after the adoption of the regulation, the use of full face protectors rose from 25% to 88% (it was 75% in 2005) with a corresponding reduction in eye injuries. The relatively few eye injuries still reported involve adult players who choose not to comply with the regulation and young participants in non-organized situations. Moreover, there is no evidence that the introduction of the full-face protector induced more neck injuries or aggressive behaviors from the players.

An update of a previous study (Régnier et al., 1995) evaluating the economic impact of this second regulation from 1988 to 2000 showed a cost/savings ratio of 1/13.7; every dollar invested by the government in the development, promotion, and enforcement of the regulation generated 13.70 of savings in health care costs.

Discussion

From the Québec experience, what would be the answer to the question "Is legislation the answer for safety in sport?" We would certainly like to answer "no," if for no other reason that it is not easy to constrain. In an ideal world, every stakeholder group (participants, manufacturers of equipment, owners of facilities, coaches, instructors, teachers, and others) would adopt safe, or safer practices on their own. But our past experience shows that this is not always the case. In fact, the presence of a governmental body such as the Québec Sports Safety Board is often essential to serve as a catalyst and a unifying force to channel and co-ordinate interventions. On the other hand, legislation alone is not the answer. In the Québec context, the powers defined in the *Act Respecting Safety in Sports* should be viewed as only one of a number of possible intervention strategies that range from education to coercion. The injury problems were approached with a multi-dimensional view, well documented facts were gathered to assess the problem, and coalitions were developed.

Summary

Implementing large-scale injury prevention programs poses many challenges. However as the examples in this chapter have shown, they can be successful and positively impact thousands of recreational to elite sport participants. In summary, we revisit the five key elements of a large-scale injury prevention program and consider specific lessons learned from our examples that are consistent with these criteria.

Approach the injury problem at hand with a multidimensional view

Both the New Zealand and Québec models had a cost/benefit ratios that were a specific part of the evaluation process. This information justifies existing efforts and creates momentum for future work (e.g., the success of the RugbySmart program helped with the development of the SoccerSmart initiative.) Without this information, sport injuries could be considered insignificant. Regarding the impact on sport, ice hockey equipment rules changes could have other effects on the game (e.g., one could argue that more aggressive play occurs because equipment makes one feel invincible). These impacts, both positive and negative, need to be identified before implementation and followed in the evaluation phase. All examples involved partnerships; a broad group of constituents to agree upon the issue and to have ownership in the solution. Pee Wee ice hockey fractures, rugby head and spinal injuries, or wrestling weight loss practices are examples of targeting a specific population and a set of injuries that has the greatest possibility of safety success in terms of both injury reduction and rehabilitation cost minimization. Focus specifically on these key issues, generate success and acceptance, and then expand as needed.

Beliefs confuse the issue: get the facts

Understanding the existing incentive to cut weight allowed for specific effective wrestling rules modification to be developed. Injury surveillance was essential in developing the scope of the problem in wrestling and in monitoring effectiveness in the RugbySmart intervention. Existing high-profile injury prevention efforts (FIFA "11"), position stands (ACSM Wrestling Weight Loss Guidelines), established models (RugbySmart, mandatory full face protection in youth hockey), and surveillance systems (NCAA ISS, ACC) were important in educating affected parties of existing medical consensus and provided a credible template. Targeted research identified the issues in the Québec bodychecking issue. Build an evaluation process into implementation and celebrate success. Follow-up research documented success in the wrestling weight loss, RugbySmart and Québec eye injury examples. These publicized successes led to further initiatives, funding and application. Success breeds success. However, understand that successes in large-scale initiative may not match results from more controlled environments due to the inherent complexities associated with educating and evaluating a much larger, less-controlled population.

Work toward a consensus: develop coalitions

Even if you are in a position to impose mandatory safety measures, make sure you develop strong grass-roots support for your intervention and identify the key stakeholders (often coaches). While the NCAA model has the capability to mandate rules, the weight management model was developed with input from a broad base to achieve ownership in the solution. In the New Zealand and Québec models, a governmental entity, national governing body, or designated position clearly responsible for the safety of sports and recreational participants with appropriate funding carried two strong messages: (1) injuries resulting from sports and recreational activities are a significant public health problem and (2) something can be done to prevent them from happening. Yet the ability for these entities to gather diverse viewpoints and ultimate consensus enhanced the success of the prevention initiatives. Having high-profile champions (coaches or athletes) promoting the cause also helps the development and acceptance process.

Recognize the limits of information campaigns: develop back-up technological systems

Public awareness campaigns are important, but they are not enough. Well-informed people are still human beings; which means that knowledge does not necessarily result in behavior change. To maximize effectiveness in educational efforts, injury prevention programs need to be engaging, current, and sport-specific, using the right language (less scientific, more plain speak) to reach the target audience. Associated resources must be stimulating and promote the enhanced performance and enjoyment benefits of programs along with injury prevention. These resources need to be designed to make it easier for the coach, referee or sporting participant to take positive action, thus increasing acceptance of injury prevention. However, backup plans are important. In the wrestling example, a long-standing position statement did not alter people's behavior as much as restricting the use of dehydration devices such as saunas and rubber suits. Field sports can minimize injury risk by well-maintained surfaces, a passive environmental modification. In ice hockey, the mandate of full-face protection and the ban of bodychecking provided socio-legislative environmental changes that had a positive impact on reducing injuries.

Try to change the perception that more safety brings less fun

One of the strong motivations drawing people to recreational activities, in particular to those practiced outdoors such as skiing, is the sense of liberty they provide. Safety is often perceived as something that will take fun away from these activities. Initiatives should promote value and fun as well as safety. For example, safety allows participation, an important selling point for coaches, players, and the national governing bodies that oversee them. Coaches, players, and referees should be alerted to injury prevention successes as soon as possible to maximize acceptance, increase participation, and further reinforce the critical role they play. Once the heavy burden of constant weight management was removed, wrestlers could spend more time on becoming better technical wrestlers. Emphasizing topics like nutrition that resonated beyond the athletic field (New Zealand model), also can have a positive impact on injury prevention on the field.

Conclusion

Conceptual advances made in the field of injury prevention in recent years show that solutions to sport and recreational injury problems have to be developed and implemented from an intersectorial perspective. The examples cited in this chapter emphasize this concept as well as the value of working from an established model or framework. We conclude this chapter with an example of a Summit on Sport Safety, organized and conducted by the province of Québec, Canada in the mid-1990s. The resulting framework established the roadmap and the initial collaboration opportunities to drive various injury prevention initiatives in the Province for the next decade. It is a model that can serve as a starting point for future initiatives in any country.

The Québec Sports Safety Board Summit on Sports Safety

In order to serve as a catalyst and a unifying force to channel and co-ordinate interventions from disparate groups, each holding part of the solution to this problem, the Québec Sports Safety Board sponsored the first summit on sport and recreation safety. The summit brought together over 80 associations and governmental agencies from education, health, and sports and recreation, both from the private and public sectors. The following stages leading to the summit were.

1. Consultation meetings: Close to 100 experts and representatives of organizations participated in five meetings. They were asked to precisely define their field of intervention and their expectations regarding the summit. It was clear that participants wanted an "action" oriented event rather than an abstract process.

2. Sports safety survey: In order to complete the consultation meetings, a questionnaire was posted to 7000 contributors from diverse sectors of intervention. Among other topics, the participants had to give their opinion on priorities for action over the years to come.

3. The program: From the consultation activities, the summit's management committee selected 13 areas of intervention resulting in the creation of 13 working groups.

4. Participant preparation: Each working group held at least one meeting before the summit. The aim of these meetings was to begin developing goals with a view to the actions required to reach those goals.

5. The Summit: The aim of the summit was to solidify each working group's action plan.

The result was 13 three-year action plans. One hundred and ten specific actions were identified, ranging from regulation modifications to social marketing campaigns. Most of the participating agencies committed themselves to carry out the actions falling within their responsibility. A flexible, easy to use follow-up system has been established to track progress and maintain the momentum of each group toward honoring their commitment.

Beyond the action plans, the most important outcome of the summit was the consolidation of a real network of organizations coming from different fields and the public and private sectors. For the first time these stakeholders were exchanging information and expertise on the common problem of safety in sport and recreational activities in Québec.

In 1990, Québec was the province with the lowest rate of sport and recreational injuries in Canada: 67/1000 participants compared with 100/1000 for the rest of the country. In 2003, Québec was still the province with the lowest rate of sport and recreational injuries in Canada. Although it is impossible to directly link these observations to the interventions identified in the Sport Summit, they strongly suggest trends in the right direction. Our evaluation is that, at the very least, the work of the government of Québec and its partners over the last 29 years has contributed to the creation of a much safer climate for sports in the province.

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Further reading

For information on the NCAA, see www.ncaa.org.

For information on the NCAA ISS, see www.ncaa.org/ISS.

For information on the New Zealand Accident Compensation Corporation (ACC), see www.acc.co.nz.

For information on SportSmart, please see www.sportsmart.org.nz.

For information on ACC RugbySmart, please see www.rugbysmart.co.nz.

For information on ACC SoccerSmart, please see www.soccersmart.co.nz.

For information on the Act Respecting Safety in Sports, see “Laws and Regulations” in www.publicationsduQuébec.gouv.qc.ca/accueil.en.html

Chapter 14
Planning for major events

Michael Turner[1] and Jiri Dvorak[2]

[1]Lawn Tennis Association and British Horseracing Authority; British Olympic Association and Chief Medical Adviser to Snowsport, UK
[2]FIFA Medical Assessment and Research Center (F-MARC), Schulthess Clinic, Zurich, Switzerland

Introduction

Major events are held all over the world on a regular basis and providing appropriate medical cover for the athletes, support staff, and spectators, as well as initiating injury prevention strategies, should be a priority for every organizer.

A major event may involve only two teams competing in front of 17,000 spectators for less than 2h on a single day but the variation is infinite. When planning a major event it is customary to appoint a Chief Medical Adviser for the event and it is essential that this individual is familiar with the hazards and risks involved in such an undertaking. In many instances this will be the same individual, or team of professionals, and it should be a priority that medical staff with experience of all the particular challenges are recruited to advise and cover the event. This is especially so in high-risk sports where medical staff unfamiliar with the sport may well find that they are ignorant of the environment and equipment in use (motor sport, equestrian sports, water sport, winter sports).

Depending on how far in advance the Chief Medical Adviser is appointed, there should be opportunities to implement emergency and injury prevention strategies and to introduce effective risk management procedures. However, these opportunities might not allow for the implementation of the standard injury prevention strategies outlined in previous chapters because these are primarily aimed at sports governing bodies, coaches, equipment manufacturers, and athletes themselves.

For example, all major events involving professional football (soccer) and American Football take place in purpose built stadia. Teams travel with their own medical support staff and there is no possibility of an event Chief Medical Adviser having any impact on the quality of the pitch, the protective equipment worn by athletes, the training technique of players, the falling technique of players, or the rules of the sport. The medical staff providing support at these events will normally have done so on numerous previous occasions and the opportunity to implement injury prevention strategies at this stage is non-existent.

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What is a "major event"?

Global events are often deemed to be "major" as a result of the huge television audiences that they attract (the 2006 FIFA World Cup was watched by 26.3 billion people in 214 countries) but this chapter will focus on those events with a large number of spectators in attendance or a large number of participants.

The largest number of spectators

For the purpose of this review, we have utilized the figures of spectators in attendance only and have identified a selection of global events that attracted an average of 17,000 or more spectators per day. The largest daily crowds are seen at the New York Marathon (2.5 million spectators) and the London Marathon (500,000) and the other major events in this category include the Tour de France cycling (434,000/day), Sydney 2000 Olympics (418,000/day), NASCAR (186,100/day), Kentucky Derby horse racing (156,400/day), Melbourne Cup horse racing (106,500/day), and Salt Lake 2002 Winter Games (95,300/day).

By comparison, the US professional sports attracted a large number of spectators over the whole season but only modest numbers attended the individual events. The figures for 2006 are as follows:

Major League Baseball—94.9 million spectators over 2419 games (30,970/event)

College Football—32.6 million spectators over 709 games (46,039/event)

NBA Basketball—21.6 million spectators over 1230 games (17,558/event)

NHL Ice hockey—20.8 million spectators over 1230 games (16,955/event)

The other sports that attract over 10 million spectators include NPB baseball (Japan—19.9 million), NFL football (USA—17.3 million), Premier League soccer (GB—12.8 million), Bundersliga 1 soccer (Germany—12.5 million), La Liga soccer (Spain—11.0 million), and the Tour de France cycling (10 million). The sports attracting 1–9 million spectators are national soccer leagues (Italy, France, Japan), the multi-sport, multi-national events (Olympic and Paralympic Games), NASCAR, and the Rugby Union World Cup.

The largest number of participants

Marathons and the multi-sport, multi-national events dominate this group—London marathon (35,500 participants), New York marathon (17,000), Sydney marathon (13,000), Sydney 2000 Olympics (10,651—16 days), US College football (6,095—709 games), Melbourne Commonwealth Games 2006 (4,500—11 days), Athens Paralympic Games 2004 (3,969—12 days), Salt Lake 2002 Winter Games (2,399—16 days), and NFL American football (1,692—256 games).

Factors to consider

The recommendations that follow are the result of a detailed review of selected major international and national sporting events that occur around the world. This "basket" of over 40 events involved 102,432 amateur and professional competitors taking part in 9,313 days of competition watched on site by over 292 million spectators (this does not include the TV audiences).

Given the vast variety of these events, the first duty of all medical staff at any sport event is to retrieve and analyze the following basic information:

- Number of sports—single or multiple
- Number of participants—individuals and/or teams
- Number of support staff—coaches, physical therapists, medics, sports scientists
- Number of spectators and VIPs
- Number of countries involved—national only, international
- Number of venues—single or multiple
- Accessibility of venues—static stadium, mobile, global
- Frequency of event—once only, repeated annually, monthly, weekly
- Number of days medical cover is required (including training and preparation days)—1 day only, weeks, months
- Special needs of the athletes—wheelchair event, blind competitors
- Special challenges of the sport—high speed, motor vehicles, horses, water, ice, snow
- Medical services traveling with the individuals or teams—team doctors, physical trainers to national squads
- Medical cover at locations other than the competition venue—hotels, athletes' village, training areas, on-call cover
- Need for specific medical subspecialties
- Governing body requirements for medical cover at events
- National legislation or guidelines in force regarding the medical cover at major events
- National legislation guidelines in force regarding temporary licenses of accompanying physicians

- Major Incident Medical Management and Support procedures (for dealing with a catastrophe on site and access to local hospital facilities)
- Accreditation of medical staff—access to venues and restricted areas
- Payments to medical staff—volunteers, travel and accommodation expenses, honorarium, uniforms, reimbursement of supplies provided by the individual.

This chapter provides an opportunity to explore some of the "best practice" issues for medical staff who have never had the opportunity to supervise or regulate an event of this size and complexity. Although many of the topics under consideration will not be seen as strictly "injury prevention measures," the underlining principle is that managing any injury in an effective and rapid fashion may well prevent further damage to the individual concerned. This will in turn lead to a reduction in the rehabilitation time and can be considered as part of the injury prevention—injury mitigation spectrum.

It is generally accepted that, following a spinal cord injury, 50% of the resulting disability is caused by the inept handling of the injured person (lack of immobilization strategy, spinal board, etc.). It can therefore be seen that having the appropriate equipment and trained personnel can significantly impact the outcome of injury and this could reasonably be included in a review of injury prevention. In addition, anything that increases the anxiety or stress levels in an athlete may well lead to a decrease in performance and event planning should be aimed at eliminating any concerns that relate to medical issues.

It is not only the competitors who are at risk in this context but also avoidable fatalities can occur amongst spectators at big sporting events. At the Winter Games in Lillehammer (Norway 1994) over 20,000 people were camped out in tents along the route of the 50 km cross-country track (overnight temperatures of –30°C). One spectator, having left the tent to find the communal washroom in the middle of the night, was apparently unable to find his way back to his tent and was discovered dead in the snow the following morning (Ekeland, 1995). At the Horseracing Derby (Great Britain 1995) a spectator who had arrived in a coach felt unwell during the afternoon and returned to the coach to rest. The coach was locked, and the sun was very hot, so he sheltered under the coach and fell asleep. The coach driver returned at the end of the afternoon and reversed the vehicle out of its parking place to prepare for departure. In the process, he ran over and killed the sleeping spectator. In both instances, the consumption of alcohol was thought to have played a significant part in the tragic outcome.

Further, some events representing special challenges are explicitly addressed and the specific points to be considered are outlined.

Major event planning tools

Basic planning

For basic planning purposes, the checklist shown in Table 14.1 provides a summary of all the pre-, during and post-event requirements.

Venue medical cover

Venue cover is relatively simple, as long as the venue is not spread out too much (Tour de France) and the event is not too large (Olympics). Cover for the participants is often provided by the teams themselves (team doctor and/or physical therapist) but facilities will need to be provided for them to treat the team members throughout the day (see checklist in Table 14.2):

- Squad treatment room at the competition venue
- Squad treatment room at the training area
- Squad treatment room at the accommodation area

These treatment rooms may be communal areas in events involving multiple sports (track and field).

Competition venues need additional attention because of the large number of spectators (and VIPs) who are in attendance (see checklist in Table 14.3).

Provisions for competitors

Competitors may never have visited the venue or country prior to the event and when planning a big event, the organizers must keep the needs of this group at the forefront of all health, welfare,

Table 14.1 Checklist basic planning.

Basic planning	Pre-event	During event
Climate—weather conditions	Review statistics for the last 10 years	Monitor and publish daily
Venues	Numbers Obtain detailed ground plans and carry out an on-site assessment Establish opening and closing times for each venue	Monitor daily and adapt medical support provision as required
Equipment	Review the equipment needed at every location where medical support will be provided	Monitor daily and adapt medical support provision as required
Athletes	Numbers and nationalities Date of arrival Time and dates of competitions and training	Monitor injuries daily
Support staff (incl. medical staff traveling with the teams or athletes)	Numbers Date of arrival Number of medical staff traveling with each team	Monitor injuries daily
Spectators	Numbers Time of access to and departure from each venue	Monitor injuries daily
VIPs	Numbers Program of VIP social events Accommodation arrangements	Monitor injuries daily
The Medical Team	Numbers needed Appoint core members and establish recruiting strategy for additional staff	Daily meetings
Training	Ensure that all members of the medical staff have appropriate training (e.g., Major Incident Medical Management and Support training—see later)	Monitor during event and arrange additional training if required
Specialist services	Access to outpatient consultations Availability of X-ray, MRI, blood pathology, etc.	Monitor access and speed of reporting
Hospital access	Identify nearest A+E unit and open a dialog with senior staff	Monitor access and speed of access
Central Medical Service—Polyclinic	Location and staffing (if required) Specialist services on offer to athletes—e.g., dental surgery	Provide medical service to all competitors, support staff, and VIPs
Communications	Establish a method of secure communication between all members of the medical staff that will protect confidentiality	Monitor daily and adapt provision as required
Record keeping	Establish a unified system for recording and analysis of all injuries and incidents	Monitor daily and adapt provision as required
Education	Prepare briefing information for visiting teams Prepare written Standing Orders for every event and every venue	Update daily by e-mail, text, or website
Insurance	Ensure that all medical staff are covered by appropriate insurance in case of accident or injury (not malpractice insurance)	Inform Insurers immediately if any accident or injury takes place that involves medical staff
Legal issues	Ensure that organizers are aware of all Government Legislation concerning the medical cover at the event and that these are complied with promptly (reporting of accidents, fatal incidents, etc.)	Review daily and notify organizing committee or relevant authority if required

Table 14.2 Checklist training venue.

Venues for training	Pre-event	During event
Planning	Establish layout and whereabouts of medical rooms and athletes area Ensure that the accreditation issued to medical staff will allow access to all areas	Monitor daily and adapt as required
Outdoor venue	Inclement weather options	Monitor daily and adapt as required
Open—closed	Hours that venue will be open daily	Publish daily hours that medical facilities will be open and list staff on site
Athletes	Numbers expected	Record and monitor all injuries or incidents daily
Support staff (incl. medical staff traveling with teams or athletes)	Number expected Provision of medical room for team medical staff	Monitor daily and adapt as required
Spectators	Number expected Provision of First Aid room	Monitor daily and adapt as required
Medical provision	Appoint venue specific medical team to deal with athletes and spectators	Monitor daily and adapt as required
Equipment	Review the medical equipment needed at each location	Monitor daily and adapt as required
Communication	Establish a method of secure communication between all members of the medical staff that will protect confidentiality of the patients	Monitor daily and adapt as required
Record keeping	Ensure access to the unified system for recording and analysis of injuries and incidents	Monitor daily and adapt as required
Access for emergency services	Identify and demark areas that must be kept clear for ambulance access	Monitor daily and adapt as required
Major Incident Medical Management and Support	Identify staff who will be responsible for co-ordinating a major incident Identify the medical assembly point for major incident (triage area, transport area, etc.) Ensure that all staff get appropriate training	Monitor daily and adapt as required
Meetings and education	Prepare Standing Orders for each venue Distribute Standing Orders to all staff in attendance	Daily debrief for venue medical staff when venue closed

and safety decisions. They will also need to take into account the accommodation and transport needs of the athletes (Table 14.4).

Teams traveling with their own medical support staff

For teams traveling without medical staff, event organizers should provide adequate numbers of doctors and physical therapists to enable all participants to be treated in a rapid and professional fashion (Table 14.4).

- General access medical facility at every competition venue (will normally include a doctor and physical therapist on site)
- General access medical facility at every training venue (may only include a single physical therapist on site and a doctor on call)

Table 14.3 Checklist competition venue.

Venues for competition	Pre-event	During event
Planning	Establish layout and whereabouts of medical rooms, athletes area, VIP areas Ensure that the accreditation issued to medical staff will allow access to all areas (especially VIP areas)	Monitor daily and adapt as required
Outdoor venue	Inclement weather options	Monitor daily and adapt as required
Open—closed	Hours that venue will be open daily	Publish daily hours that medical facilities will be open and list staff on site
Athletes	Numbers expected	Record and monitor injuries and incidents daily
Support staff (incl. medical staff)	Number expected Provision of medical room for team medical staff	Monitor daily and adapt as required
Spectators and VIPs	Number expected Provision of First Aid room and mobile staff required	Monitor daily and adapt as required
Medical provision	Appoint venue specific medical team to deal with athletes and spectators	Monitor daily and adapt as required
Equipment	Review the medical equipment needed at each location	Monitor daily and adapt as required
Communication	Establish a method of secure communication between all members of the medical staff that will protect confidentiality	Monitor daily and adapt as required
Record keeping	Establish a unified system for recording and analysis of all injuries and incidents that occur during the event	Monitor daily and adapt as required
Meetings and education	Invitation for team medical staff to visit venue prior to start of competition Prepare Standing Orders for each venue	Daily debrief for venue medical staff when venue closed

Table 14.4 Checklist competitors.

Competitors	Pre-event	During event
Arrival	Numbers Date of arrival	
Accommodation—hotel or village	Location and access details Identify all security-related issues	
Training facilities—gym	Location Nearest access to medical staff and facilities	
Training venue	Location of changing and training areas Access to medical room, van, or tent Medical staff on site	Publish Opening times of team medical rooms and how to access the medical support provided by host (24 hr emergency numbers etc.)
Competition venue	Location of changing and training areas Access to medical room, van, or tent Medical staff on site	
Central Medical Service—Polyclinic	Hours of opening Rota of medical staff	
Education	Briefing literature with details of all medical services, emergency numbers, and maps (city and venues)	Update daily by e-mail, text, or website

- General access medical facility at the athlete village (will normally include a doctor and physical therapist on site)
- On call arrangements to cover "out of hours" periods when other facilities are closed.

Medical indemnity and international competition

Medical staff traveling abroad provides a particular challenge for organizers because of the medical–legal issues surrounding their national qualifications. Within the European Union, medical staff are free to practice in an unrestricted fashion but this does not apply when traveling to North America or Australia. Doctors and therapists may not be insured to practice abroad and will certainly not be entitled to obtain medicine on prescription in a foreign country. The organizers need to communicate the need for a temporary licensing procedure to all visiting physicians in advance. The organizers must therefore make arrangements for visiting medical staff to have access to:

- A pharmacy (or access to a doctor employed by the organizing committee to write the necessary prescriptions)
- A pathology laboratory—blood testing, swabs, urinalysis
- X-ray and imaging facilities
- Specialist opinion
- Dental care
- Ophthalmology, facio-maxillary surgery, orthopedic surgery, etc.

One way of ensuring that this runs smoothly is to appoint locally established doctors who can serve as mediators for the visiting medical staff and facilitate access to all services.

Medical cover for the spectators

This often poses the biggest challenge to the organizers and their Chief Medical Adviser. In many cases, nation law is in place that mandates the minimum standards of medical cover at large events and individual venues may have safety certificates that control capacity and the support services required on site. Table 14.5 provides a checklist covering spectator issues.

At any venue where large numbers of people congregate, the opportunity for the medical resources to be totally overwhelmed by a major incident must be addressed. In an era where terrorist activities occur on an annual basis, we also have instances where accidental explosions (cooking gas) or stand collapse have occurred at sporting events.

These events require close co-operation between all the emergency services (police, fire service, and ambulance service) and the medical team on site. Indeed the emergency services may not be deployed on site for 30 min or more (particularly in rural locations) and the only medical support available will be the event team.

Major Incident Medical Management and Support requires particular training and all medical staff providing cover at a big event should ensure that they have completed an appropriate training course. In the United Kingdom, the standard course takes place over 4 days.

As a result of a number of high-profile disasters at football events in the United Kingdom, the Health and Safety Executive published the *Guide to Safety at Sports Grounds* (ISBN 978 0 11 702074 0) which covers all aspects of spectator cover (Figure 14.1). These guidelines indicate the minimum level of medical cover expected for sporting events and a summary is included in Table 14.6 to help those practitioners who have no national guidelines to follow.

Very Important People

Organizers should be aware that although a few VIPs are actually former world class athletes, the vast majority are not in perfect physical shape. Despite this, they all expect to be treated as if they were potential medalists and when illness or injury occurs, all other medical resources may need to be diverted. At a single international event (UEFA Cup Final) VIPs may include Heads of State, Royalty, Prime Ministers, and Presidents of International Governing Bodies as well as their partners, children, and guests. A call to attend a collapsed VIP can severely compromise the normal spectator medical support provided and diverting the athlete medical cover is not an option. It may therefore be necessary to recruit additional

Table 14.5 Checklist spectators.

Spectators	Pre-event	During event
Arrival	Numbers expected Time of access to facility	Monitor and update daily
Duration	Days of medical cover needed Hours of access to medical staff	Monitor and update daily
Venue	Indoor stadium Outdoor stadium Outdoor urban Outdoor rural	Monitor and update daily Provision for inclement weather
Medical support	Medical room, van, or tent Triage points Number and type of medical support needed Equipment required	Monitor and update daily
Equipment	Review the medical equipment needed at each location	Monitor daily and adapt as required
Record keeping	Ensure access to the unified stem for recording and analysis of all injuries and incidents	Monitor daily and adapt as required
First Aid support	First Aid room, van, or tent Number and qualification of First Aid staff needed Equipment required	Monitor and update daily
Communication	Independent communication network for all medical staff with responsibilities for spectators	Monitor and update daily
Medical equipment for use by non-medics	Access to automated defibrillators on site	Monitor and update daily
Pharmacy	On site Nearest to venue Opening times	Monitor and update daily
Catering	Adequate for the numbers and duration	Monitor and update daily
Sanitary facilities	Adequate for the numbers and duration	Monitor and update daily
Major incident	Ensure that a details major incident plan has been agreed with the local police, fire brigade, and ambulance services Identify staff who will be responsible for co-ordinating a major incident Identify the medical assembly point for major incident (triage area, transport area, etc.)	Monitor and update daily
Education and training	Clear signage to medical facilities Standing Orders covering all aspects of spectator medical cover	Daily medical staff meeting after venue closed Update daily by e-mail, text, or website

medical resources solely to cover these individuals for the period that they are in attendance at a major event. It should also be noted that the security for these individuals is usually managed by the Military or Secret Service and access to the immediate area is impossible to achieve without the necessary accreditation and vetting. This cannot be achieved at the last minute. Table 14.7 provides a checklist for VIP medical coverage.

Selection and training of medical staff: the multi-disciplined approach

Medical support at a major event will not be restricted to doctors and physical therapists alone and consideration should be given at an early stage to the mix of staff required for any particular event or venue. These individuals may not be required to be present on site during competition or training

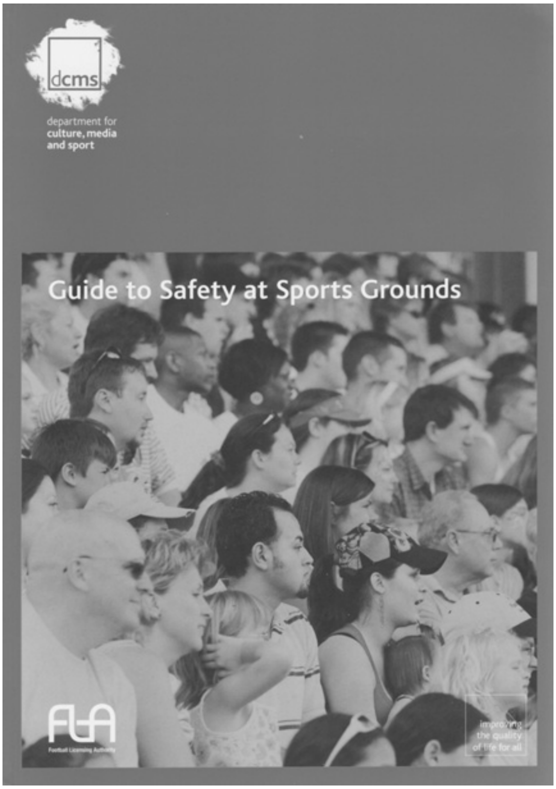

Figure 14.1. *Guide to Safety at Sports Grounds* (2008)

but will normally include a mix of doctors, paramedics, nurses, physical therapists (physiotherapists, osteopaths, chiropractors, sports therapists, massage therapists), dentists, podiatrists, sports scientists (nutritionists, sports psychologists), and First Aid trained staff. Table 14.8 provides an overview of factors to be considered related to selection and training of medical staff.

Events requiring special attention

High-risk events (including those taking place at extremes of climate or high altitude)

A number of events involve additional risk to the competitors because of the nature of the event or the location in which it takes place. These events provide a much greater challenge to medical support staff and include the outdoor winter sports and water sports, equestrian sports, and high speed sports (motor racing and motor cycle racing). These are invariably associated with a much higher incidence of significant injury and fatality.

Medical support staff at these events must be familiar with the sport concerned, the environment in which it takes place and the type of injury that can be expected. These events require all the basic cover outlined earlier but additional consideration will need to be given (see Table 14.9).

Disability sport and spectators in wheelchairs

Medical support for disability sport is essentially identical to that already outlined apart from the following areas—support staff, transport, and access. However, the support staff/athlete ratio is normally higher for events involving disabled players. Suitable accommodation and transport needs to be available for these individuals to avoid additional stress for the athletes concerned. Wheelchair competitors use one type of chair for competition and another for normal activity. When organizing transport for wheelchair events, it must be possible for competitors to travel with a spare wheelchair to the training or competition site. For events involving wheelchairs, access into and out of transport vehicles, accommodation, competition and training venues, changing rooms, medical facilities, and spectator areas must be reviewed and may need to be adapted (Table 14.10).

Marathon

The two sporting events with the largest number of competitors in this analysis are both marathons and they provide an excellent model for exploring injury prevention strategies.

The London Marathon has been run continuously since 1981. Of the 131,000 applicants in the London Marathon only 48,000 (36.6%) are accepted as participants. The age range 18–88 years with a gender bias (69% male/31% female). Of these, 35,557 will actually start the race (74.1% of the accepted application) but over 99% of these will now expect to finish the race. This figure has climbed from 88.7% in 1981 as a direct result of the management strategies

Table 14.6 Minimum level of medical cover at sport events.

Minimum of two First Aid trained staff at every event
- At least one First Aid trained person for every 1000 spectators (up to 20,000 spectators)
- Over 20,000 spectators—additional one First Aid trained person for every 2000 spectators

Each First Aid trained person must be
- Over 16 years of age
- Have no other duties or responsibilities
- Be in post before the first spectator enters the ground
- Remain in post until all the spectators have left

A designated First Aid room with specified
- Size
- Fittings and facilities
- Design and location
- Storage, equipment, and materials
- Upkeep and inspection schedule

One crowd doctor should be employed when it is anticipated that the crowd will exceed 2000 spectators
- The crowd doctor must have suitable training and experience
- The whereabouts of the crowd doctor must be known to all First Aid and ambulance staff at all times (communications)
- The crowd doctor must be on site before the first spectator enters the ground and remain on site until all the spectators have left
- The crowd doctor must have no other duties or responsibilities during this period (e.g., be a team doctor as well)

At least one fully equipped accident and emergency ambulance to be on site for all events with an anticipated attendance of over 5000 spectators

Crowds 5000 to 25,000
- One fully equipped accident and emergency ambulance (with a paramedic crew)
- An ambulance officer

Crowds of 25,000 to 45,000
- One fully equipped accident and emergency ambulance (with a paramedic crew)
- An ambulance officer
- One major incident equipped vehicle with a paramedic crew
- One control unit

Crowds of over 45,000
- Two fully equipped accident and emergency ambulance (with a paramedic crews)
- An ambulance officer
- One major incident equipped vehicle with a paramedic crew
- One control unit

introduced by the organizers of this highly successful event.

Health questionnaire and medical clearance

All applicants are required to complete a health questionnaire and to provide a statement from their own medical practitioner that they are "fit to run." The Chief Medical Adviser of the event must be prepared to monitor and manage the information provided on the health questionnaires to assist in providing the necessary medical support for participants. It should also be noted that because marathons are now used as fund raising opportunities by many charities, the majority of the participants will have no special sporting skills and a significant number may be disabled.

Education

Once accepted, each competitor should be provided with a detailed education leaflet outlining a simple training program and providing advice about nutrition, fluid intake, sleep, and rest.

Climate

This should include a review of the different strategies that might be needed under different climatic conditions. In London, experience has shown

Table 14.7 Checklist VIPs.

VIPs	Pre-event	During event
Arrival	Dates of arrival Numbers expected Requirement for interpreting service	Monitor daily and adapt as required
Accommodation	Location and numbers in hotels, staying with friends	Provision of medical services at accommodation (house call) throughout the event
Attendance at training venues	Establish impact on venue medical services	Provision of dedicated medical cover if required (see later)
Attendance at competition	Establish impact on venue medical services	Provision of dedicated medical cover if required (see later)
Security	Establish impact on venue medical services Ensure correct accreditation for medical staff (see later)	Ensure correct accreditation for medical staff (see later)
Education	Briefing literature with details of all medical services, emergency numbers and maps (city and venues)	
Health record	Submit health record pass to all participating organizations and ask them to have it completed by VIP physicians	Safely store sealed records to have them at hand in case of emergency

that an ideal temperature for a fast event is 10–12°C but the actual temperature range has been 5.9–21.0°C over 25 years. Humidity has ranged 28–96% and this will have an effect on clothing and fluid intake.

The media

Education can be greatly enhanced by utilizing media programs (particularly TV) to follow groups of novice runners as they prepare for the event. This has proven particularly effective in Australia and in Great Britain; children's TV programs are regularly used to educate children taking part in mini-marathon and "fun run" events.

Venue preparation

A typical marathon will have water stations every 1.6 km (from the 4.8 km mark) with access to sports drinks every 8 km (starting at the 8 km mark). Special drinking stations are also set up for the elite runner group where they can place their own prepared drinks—a total of eight along the 42.2 km course (approximately every 5 km). Adequate barriers will be erected to separate the competitors from the spectators and regulatory arrangements need to be coordinated with event marshals and police. In London 2006, there were 1100 marshals at the start, 3050 along the route, and 2500 at the finish—a total of 6650. Portable toilets need to be available for competitors at the start, along the course and at the finish (total of 950 in London 2006 race). First Aid stations (39) and First Aid staff (1200) are required to assist those who get into difficulties with suitable equipment (500 stretchers) and transport (68 ambulances) to cater for the more serious cases.

In events of this sort, the needs of the elite athletes and those of the amateurs may be completely different and provision will need to be made for both groups separately.

Other Olympic sports

All the 29 summer and 7 winter sports run regular events on an annual basis. Many of these will be classified as big events (World Championships) and appropriate medical cover will be needed. The general principles outlined earlier can be applied to all these events, but a number need to be emphasised.

Table 14.8 Checklist medical staff.

Medical staff	Pre-event	During event
Planning	How many days How many competitors How many spectators How many venues Location and scope of the Polyclinic	Review and update daily
Appointment of staff	How many medical staff needed Selection of core staff for venues, Polyclinic and spectator duties Make provision for extra staff in case of illness or domestic crisis Obtain documentary evidence that all medical staff are suitably qualified, currently registered with their professional organization and have appropriate malpractice insurance	Review and update daily Communicate with on-call staff daily to ensure availability at short notice
Training	Ensure that all staff have appropriate qualifications for the duties they have been assigned Arrange appropriate specialist training for some staff (see Major Incident Medical Management and Support—later) Training to use the communication system	
Rehearsal	Ensure that all staff are familiar with the venues and have had an opportunity to rehearse the extraction of an injured player or spectator Ensure all staff are familiar with and can use the chosen communication system	
Arrival and attendance	Organize a rota for every member of the medical staff with appropriate rest periods and days off	Review and update daily
Venue cover—athletes	Number of expected athletes and times of attendance at venue Ensure that all staff are familiar with venue and the sports (events) that will take place in that venue Establish the means of communication at the venue and ensure that it works in all parts of the venue Establish if the event will involve disabled competitors—wheelchair access required	Review and update daily Monitor all injuries and attendance Daily debrief meetings of all venue staff after event has finished Daily report to Chief Medical Advisor or nominated deputy every day
Venue cover—spectators	Number of expected spectators and times of access to venue Ensure that all staff are familiar with the venue and the times that spectators will be on site Establish if the event will involve disabled spectators—wheelchair access required	Review and update daily Monitor all injuries and attendance Daily debrief meetings of all venue staff after event has finished Daily report to Chief Medical Adviser or nominated deputy every day
Polyclinic cover	Number of staff Times of opening	Review and update daily Monitor all injuries and attendance Daily debrief meetings of all staff Daily report to Chief Medical Advisor or nominated deputy every day
VIP cover	Designated staff to deal with VIP problems throughout event—provide 24 h emergency contact number	Review and update daily
Equipment and communication	Establish exact levels of equipment to be located at each venue, to be carried by each doctor and first aider, to be available in the Polyclinic Obtain sufficient walkie-talkies for all medical staff	Review and update daily

(*Continued*)

Table 14.8 (Continued)

Medical staff	Pre-event	During event
A+E and transport	Number of ambulances and Paramedics needed Location of nearest A+E department Mechanism of referral to A+E department Capacity and waiting times of A+E department Specialist investigations available at this hospital (neurosurgery unit?)	Review and update daily
Outpatient services	Establish the system for outpatient referral (ophthalmology, urology, gynecology) and how to obtain other investigations (MRI, X-ray, pathology) Establish who will be responsible for payments (the individual athlete or spectator, the organizing committee, National Health Service, Insurance company)	Review and update daily
Education	Meetings with all medical staff prior to event Briefing literature for all medical staff with maps and contact details for senior staff and emergency services	Daily medical staff meeting after venue or clinic closed Update daily by e-mail, text, or website
Legislation	Ensure that all medical staff are aware of the Government Legislation relating to medical cover at the event (reporting of accidents, fatal incidents, etc.)	Ensure that all medical staff comply promptly with the Government Legislation relating to medical cover at the event (reporting of accidents, fatal incidents, etc.)
Insurance	Ensure that all medical staff are covered by appropriate insurance in case of accident of injury and have appropriate malpractice insurance (copies of all the current malpractice insurance certificates should be kept on file by the organizers)	
Financial issues	Establish number of paid staff and volunteers needed Prepare and agree budget (signed letter of agreement) Method and timing of payments to medical staff agreed—to include training and rehearsal days (venue visits)	Review and ensure that agreed payments are made

Standing Orders

Standing Orders must be prepared for every event and must include the deployment and duties of all medical staff. Prior to every event, these must have been read and understood by all staff on duty at an event. It is strongly advised that all medical staff are required to sign a declaration that they have read and understood the Standing Orders prior to officiating at an event.

Supplies and equipment

Medical staff must be familiar with all the supplies and equipment that they are carrying or have access to. These must be checked daily and before every event, all items must be in working order and not out of date. A list of all the supplies and equipment held on site, and those carried by the medical staff, must be listed in the Standing Orders.

Briefing

Before every event, a detailed briefing should be carried out by senior medical staff. This may include input from the Senior Medical Officer on duty, the emergency services (paramedic and ambulance crews), and the First Aid providers. *It cannot be emphasized how essential this is to the efficient running of an event.*

Communications

All staff must have access to a central communication system, they must be trained in using this

Table 14.9 Checklist high-risk sports.

Specific issues in high-risk sports	Pre-event	During event
Winter sports (Alpine and Nordic skiing, Luge, Skeleton and Bobsleigh)	Establish the medical criteria mandated by the governing body for medical cover at the event In skiing events these may also include criteria prohibiting the event from taking place in inclement weather (low temperate, high wind speed) Ensure that appropriate rescue equipment and personnel are recruited (blood wagons, ski patrols) Ensure that staff who are on site can rapidly reach all parts of the area they are responsible for (that they can ski or have the use of a snowmobile) Ensure that medical staff are familiar with the personal protective equipment used by participants Establish process whereby the event can be delayed or halted if a serious injury occurs	Monitor and review the management of every injury and adapt medical support as necessary Halt event if medical support staff are required to leave the site and resources are limited Daily debrief meeting essential
Outdoor water sports—including multi-sport events with a swim element (sailing, windsurfing, triathlon, Iron man)	Establish the medical criteria mandated by the governing body for medical cover at the event Ensure that a suitable water-based rescue system is in place which enables medical staff to rapidly reach all parts of the area they are responsible for Ensure that rescue staff can swim and have suitable safety equipment allocated Ensure that medical staff are familiar with the personal protective equipment used by participants Establish a process whereby the event can be delayed or halted if a serious injury occurs	Monitor and review the management of every injury and adapt medical support as necessary Halt event if medical support staff are required to leave the site and resources are limited Daily debrief meeting essential
Equestrian sports (horse racing, 3-day eventing, polo)	Establish the medical criteria mandated by the governing body for medical cover at the event Ensure that medical staff are familiar with the personal protective equipment used by participants Establish a process whereby the event can be delayed or halted if a serious injury occurs	Monitor and review the management of every injury and adapt medical support as necessary Halt event if medical support staff are required to leave the site and resources are limited Daily debrief meeting essential
Motor sports (Formula 1, motor cycle racing, drag racing, NASCAR)	Establish the medical criteria mandated by the governing body for medical cover at the event Establish a process whereby the event can be delayed or halted if a serious injury occurs	Monitor and review the management of every injury and adapt medical support as necessary Halt event if medical support staff are required to leave the site and resources are limited Daily debrief meeting essential
Events taking place at high temperature or altitude	Specialist staff (physiologists) must be recruited to advise medical staff and competitors of the particular risks involved in due advance and publish recommendations on adequate preparation	Daily distribution of expected weather conditions
Emergency transport—ambulances and helicopter	Ensure that additional emergency transport is on site or on immediate call to evacuate the expected major trauma cases	Monitor and review daily

(*Continued*)

Table 14.9 (*Continued*)

Specific issues in high-risk sports	Pre-event	During event
Communications	Highest priority All staff must be given suitable equipment and trained to use it All communications equipment must be able to function in inclement weather and across the whole venue site (many kilometers)	Monitor and review daily
Training	Ensure that all staff are suitably qualified and trained to deal with the injuries that they will encounter. This may include ATLS training in cases where major trauma is expected (equestrian and motor sports)	
Insurance	Ensure that all medical staff are covered by appropriate insurance in case of accident of injury and have appropriate malpractice insurance (copies of all the current malpractice insurance certificates should be kept on file by the organizers)	

Table 14.10 Checklist disability staff.

Disability sport	Pre-event	During event
Athlete support staff	Ensure that adequate provision is made for additional individuals—accommodation, medical support	Obtain daily feedback from athlete support staff Review existing arrangements and adapt as necessary
Transport	Ensure that suitable transport is available at all times	Review daily and arrange for deficiencies to be rectified
Access	Ensure that access to all areas needed by disabled athlete's is easy and safe	Review daily and arrange for deficiencies to be rectified

equipment and the equipment must be tested before the event starts. To preserve confidentiality, it is essential that the network used for medical communication is not shared with other non-medical staff.

Training and Major Incident Medical Management and Support

All medical staff must be appropriately trained and qualified to undertake the duties they have been allocated. In events that include large crowds, this may include additional training in major incident management.

Security and accreditation

All medical staff must be able to move freely from venue to venue and from area to area (spectators, athletes, training, etc.) within each venue. Careful consideration needs to be given to the levels of accreditation needed under these circumstances.

The unexpected event

It is clearly not possible to predict the unpredictable but the need for flexibility and having a contingency strategy for sudden unforeseen problems is essential in the preparation for any major event. History has a habit of repeating itself and the need to review similar sporting events that have taken place in the past, to plan for the unexpected, and to pay meticulous attention to detail cannot be emphasized enough.

On 27th July 1996, a bomb in the Centennial Olympic Park in Atlanta killed one spectator and injured 111 others.

In 1998 during the Sydney to Hobart yacht race, 6 boats sank or had to be abandoned in atrocious weather, 50 sailors had to be rescued from the water by helicopter and 6 sailors died. Only 2 fatalities had previously been recorded in the 54 race history.

The Paris-Dakar rally has resulted in at least 48 competitor deaths in its 28-year history with an even larger number of spectators' deaths. Organization of a race that takes place over 10,000 km in some of the most inhospitable terrain on the globe is a significant challenge.

Competitors have been assaulted by members of the public (Monica Seles).

Assaults involving spectators are more frequent in soccer and rugby when the national team wins and the number of assaults increases as the crowd gets larger, irrespective of the location of the game (home or away) (Sivarajasingam et al., 2005).

Alcohol is frequently associated with disturbances amongst spectators and some events ban the sale or consumption of alcohol on site. Well-documented sporting disasters have involved stands collapsing, stampedes, spectators being crushed, fires, and locked exits. Events taking place in remote locations can easily overwhelm the local emergency infrastructure, including the local district hospital which may have very limited specialist cover and no neurosurgical or burns unit on site.

Sub-zero temperatures result in ice formation and spectators will be at considerable risk when walking on this surface. At the ski jumping at Lillehammer 1994 Olympics, fine sand was used to prepare the paths used by spectators but this was rapidly incorporated in a layer of ice as the day progressed. This resulted in a large number of spectators falling and suffering fractures when returning to the village after the event. Coarse gravel was used on subsequent days and the incidence of fractures plummeted.

Post-event activities

Following any major event, an audit should be undertaken to review the positive and negative experiences and make recommendations about future events of this sort. These results should be published whenever possible to enable other organizers to share your experiences (Budgett et al., 1997; Junge et al., 2004; Junge et al., 2006; Dvorak et al., 2007). In certain circumstances these may form the basis of guidelines for the organization of major sporting events (*Guide for Managing risk in Motor Sport*, 2007).

Conclusion

The challenges presented in planning a major event are virtually unlimited. However, by carefully identifying the basic requirements and by using the specific planning tools outlined in this chapter, the organizers will find that the process becomes manageable. A structure can be imposed on the event and medical planning can be positively channeled to minimize the risk of injury or disaster.

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Further reading

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