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Sports injuries in children

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Introduction: Sports injuries in children affect both growing bone and soft tissues, and can result in damage of growth mechanisms with subsequent lifelong, growth disturbance. This clinical review unfolds the incidence and distribution, physiology, injury characteristics and the prevention modalities.

Methods: A comprehensive in Medline literature search was performed, and the reference lists of sports injuries related journals and text books was consulted.

Results: During growth, there are significant changes in the biomechanical properties of bone. In young athletes, as bone stiffness increases and resistance to impact diminishes, sudden overload may cause bones to bow or buckle. Fractures that are initially united with some deformity can completely remodel, and the bone may appear totally normal in later life.

Discussion/conclusion: Most injuries caused in children's sports are minor and self-limiting, suggesting that children and youth sports are safe. The training programmes should take into account their physical and psychological immaturity, so that growing athletes can adjust to the changes in their bodies.

Keywords: musculoskeletal system/epidemiology/upper limb/lower limb/spine/children/sports injuries

Introduction

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Physical activity plays a significant role in the well-being of a child. A well-designed exercise programme enhances the immediate physical, psychomotoric and intellectual attainments of a child.[1] Long-term health benefits depend on continuation of the physical activity, thus enhancing well-being and favouring the balanced development of a child.[1] In the last two decades, competitive sports participation has become an established feature of childhood in Western countries.[2] The past decade has seen an explosion in the number of children participating in team and solo sports. At a young age, sport is for enjoyment and for health and personal development.[3] This balance changes as a competitive element intervenes. Subsequently, young athletes train harder and longer and participate in sport throughout the whole year. As an undesired but inevitable consequence, sports-related injuries have increased significantly.[4–7]

Incidence and distribution of sport-related injuries vary based on sport affiliation, participation level, (e.g. grade level, age and skill level), gender and player position.[8] The actual incidence of injury in children's sports is very difficult, if not impossible, to determine. Published studies vary significantly in terms of populations studied, methodology used and types and severity of injuries reported. In addition, because of the different criteria used to define an injury, comparisons between reports are difficult, and any such comparisons should be interpreted with caution.

The range of age in which individuals can be considered children are as follows: young children are between 2 and 6 years, older children are between 6 and 13 years, and teenagers are between 13 and 19 years old. There is no evidence of age range difference among male and female children. In the UK, 79% of children aged between 5 and 15 take part in organized sport, 11% of whom are involved in intensive training.[9] In the USA, up to 50% of boys and 25% of girls between 8 and 16 years take part in organized competitive sport.[10]

Approximately 3–11% of school children are injured per year while participating in sport. Twice as many boys as girls sustain sports-related injuries.[11–14] Some authors report a similar incidence between the genders.[15,16] Boys, however, still sustain more severe injuries, possibly because they are more aggressive. For certain sports, such as horse riding, injuries are four times more common in females.[13] While the incidence of sports injuries in several sports are considered, sports involving contact and jumping have the highest injury levels, with American football in particular accounting for the majority of injuries followed by wrestling, basketball, soccer and baseball. Among girls, soccer had the highest injury rate, followed by basketball, field hockey, softball and volleyball.[16–18] Elite athletes, however, have lower injury rates than the general sporting populations.[19] Using a mixed longitudinal study design, an incidence rate of less than one injury per 1000 h of training in 453 elite young British athletes was reported.[20] In general, the incidence of sports injuries seems to increase with age, approaching the incidence rate of senior players in the older children.

Schmidt and Höllwarth[13] compared the frequency of sport injuries according to their location. They found that 43.8% of all injuries occur in the upper extremity, 34.5% in the lower extremity and 16% in the head, and peak at the age of 12. Sprains, contusions and lacerations account for the majority (60%) of injuries.[13,21,22]

The musculoskeletal system in childhood

To understand children's injuries, it is important to have an insight into the peculiarities of the growing musculoskeletal system. Tendons and ligaments are relatively stronger than the epiphyseal plate and considerably more elastic. Therefore, in severe trauma, the epiphyseal plate, being weaker than the ligaments, gives way.[23–26] Subsequently, growth plate damage is more common than ligamentous injury.[12,27–31]

In children, bones and muscles show increased elasticity and heal faster.[12,32–34] Around the period of peak linear growth, adolescents are vulnerable to injuries because of imbalance in strength and flexibility and changes in the biomechanical properties of bone. In immature athletes, as bone stiffness increases and resistance to impact diminishes, sudden overload may cause bones to bow or buckle. Physiological loading is beneficial for the skeleton, but excessive strains may produce serious injuries to joints.[12] Low-intensity training can stimulate bone growth, but high-intensity training can inhibit it.[35,36] There are adaptive changes to sport activity, and up to puberty muscular strength is similar in girls and boys.[15,37] Sports injuries affect bone and soft tissues, and, because the skeleton is growing, injuries can result in progressive permanent effects.[4,5,12,15,38] Growth plate disturbances as a result of sports injuries can result in limb length discrepancy, angular deformity or altered joint mechanics, and may cause significant long term disability.[39]

Children produce more heat relative to body mass, have a low sweating capacity, and also tend not to drink enough compared with adults.[15] Therefore, heat exhaustion, especially in hot climates, is more likely than in adults. This may result in an increased number of injuries.[15]

Risk factors

There are a number of well-established risk factors for paediatric musculoskeletal injury in sport.[40–43] With growth spurts, there is a decrease in flexibility because of relative bone lengthening. This predisposes to injury in the absence of appropriate stretching exercises, prior to commencing sport. Recent studies, in adults, have shown that stretching prior to exercise does not reduce the incidence of injury,[44,45] although it remains to be seen whether this is also the case in children. Training in improper environments or with incorrect footwear equipment can also result in injury. Cross training and gradual change in training schedules is good practice. Players should ideally be matched for body size, athletic ability and biological maturity with appropriate body protection and supervision.[46,47] Balanced nutrition is vital: amenorrhoeic anorexic females with reduced bone mineral density are at higher risk of injury.[48,49] High-resistance training may also predispose children to an increased risk of injury, if not properly supervised.[50]

Injury characteristics and severity

Injuries can either occur acutely and are associated with a macro-traumatic event, such as fractures and sprains, or arise gradually due to a repetitive microtraumatic event, such as stress fracture, osteochondritis dissecans (OCD), apophysitis or tendinopathies.[51] Presentation for macro-trauma is invariably not delayed. There is typically a good clear history and mechanism of injury. On examination, there will be pain and, depending on the area of the body, swelling and deformity. This will allow the examiner to determine a likely diagnosis and whether any further investigations are warranted. Luckily, the majority of injuries are minor and require a short period of rest, analgesia and compression prior to graduated formal rehabilitation. Microtrauma or overuse injuries invariably give a more insidious onset of symptoms that are typically related to activity. These symptoms will obviously depend very much on the anatomical location. In the younger individual, they may present purely with reduced performance or a limp. Exact identification of the anatomical area injured can be difficult. History and examination are vital. The type of sport played may give extra clues to the likely diagnosis, although further investigations may be required to confirm the diagnosis. Management generally requires a period of relative rest with the child partaking in a different sport to allow healing while maintaining general condition. If this fails, then rest must be absolute and referral for specialist assessment is advisable. Coaches are appropriately advised to observe attitude, behaviour and development which may suggest neglect or abuse. This may be evident acutely or present as if there is a chronic injury.

The severity of injuries spans broadly from sprains and contusions to death, and certain types of injury occur more commonly in specific sports. For example, spiral fractures of the tibia are the most common fracture in children with skiing injuries,[52,53] in basketball, ankle injuries are the most common injury seen.[54] Fortunately, the vast majority of sports injuries are minor and do not require medical attention. Very serious sports accidents in youth, such as brain or spinal cord damage, lesions of the heart or submersions leading to invalidity or death, are exceptional.[18]

Common injuries

Dislocations

Glenohumeral

Dislocation is uncommon prior to closure of the growth plate, as the growth plate is the weakest area in the event of a fall. Dislocations in adolescents are typically traumatic, but multiaxial instability must be excluded. Recurrence is highly likely due to age and the traumatic nature of injury.[55] Accompanying soft tissue injuries are common, especially affecting the rotator cuff and biceps tendon. Excessive throwing, in sports such as baseball, can damage the glenoid labrum.

Elbow

Dislocation of the elbow is common in gymnastics and football. It can be associated with fractures of the medial epicondyle of the humerus, fractures of the neck of the radius or injury to the median or ulnar nerve. Most dislocations in youngsters are posterior or posterolateral. Prompt reduction is required at all ages. Rehabilitation should be active, and we discourage return to sporting activities before 8–12 weeks. The child should have regained a full range of movement before resuming full sporting activity.

Patella

Patellar subluxation or dislocation occurs in 1 in 1000 children aged between 9 and 15.[56] A common cause is a twisting injury, when the femur is twisted medially with the foot planted on the ground, or direct trauma. Patella alta predisposes to patellar instability and may be accompanied by chronic low-grade knee pain due to patellofemoral stress syndrome.[12,57] Spontaneous reduction is possible, and the patient may present with an effusion at times, due to injury of the anterior cruciate ligament (ACL).[58]

Management consists of immediate reduction of the dislocated patella, and adopting the PRICE [protection of the injured joint (plaster cast or posterior splint), rest, ice, compression, and elevation to control inflammation] principle.[59] Immobilization of the knee joint should be limited to 3 weeks to avoid muscle atrophy, knee joint restrictions and retropatellar crepitus. Static quadriceps and hamstring muscle strengthening exercises are started as soon as pain allows, aiming at returning to sports in 4–6 months after the dislocation. However, one in six patients will develop recurrent dislocation and will require realignment surgery. Skyline radiographs are recommended to exclude marginal osteochondral fractures that can result in loose body formation.[12]

Fractures

Clavicle

A common injury in contact sports and in sports involving falls onto the outstretched hand or a direct fall onto the shoulder. The younger the child, lesser is the deformity, due to the greenstick variant of injury and fractures within a thick periosteal tube.[60] Comparative radiographs are helpful if the injury affects an ossification centre. Reduction is generally not necessary, and the child simply needs a sling to immobilize the arm for 2–3 weeks. Generally, recovery is excellent.

Humerus

Metaphyseal fractures are commonly seen, particularly in older children. The mechanism of injury is usually indirect. It is rarely necessary to correct the deformity, given the great adaptability of the shoulder joint and the good remodelling seen at this site.

Supracondylar fractures of the humerus occur as a result of a fall onto the outstretched hand. The distal part of the humerus most commonly displaces posteriorly and can involve the growth plate (Fig. 1).

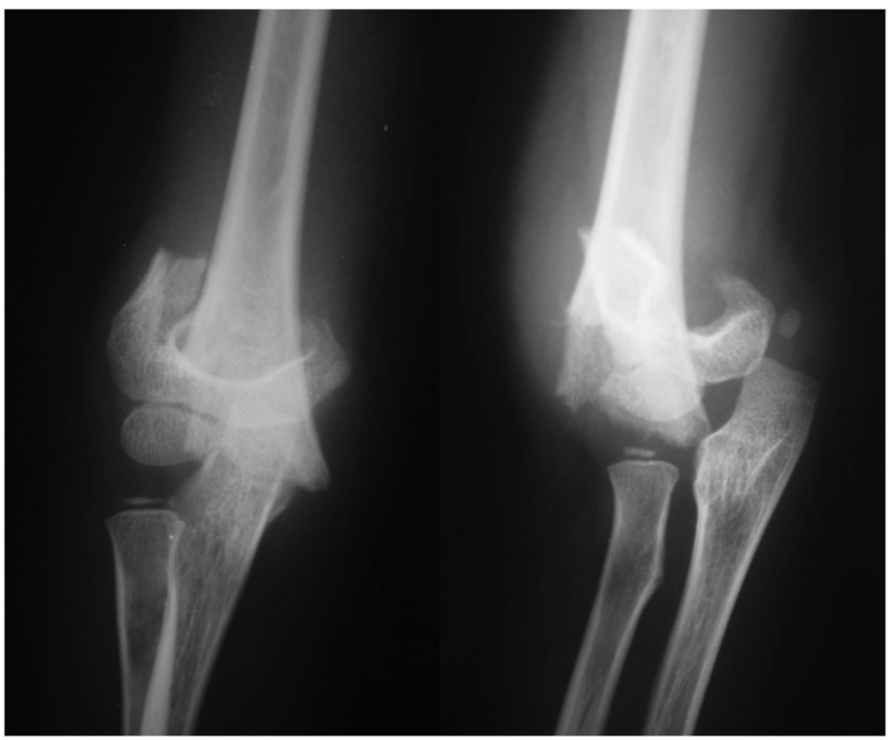

Fig. 1 Anteroposterior and lateral view radiograph of a supracondylar fracture of the right humerus.

The injury may be associated with damage to major vessels or nerves. The arm should be manipulated correcting all the components of the fracture and held either in flexion or in extension, depending on the type of fracture, in a well-moulded cast.[61] It is necessary to make sure that there is no associated brachial artery injury. If this is the case, surgical exploration with open reduction is mandatory. If the closed reduction is acceptable—but unstable—percutaneous wiring can be used to maintain reduction.[62] If it is not possible to achieve a satisfactory closed reduction, then open reduction is indicated. The elbow is liable to develop post-traumatic stiffness, and damage to the growth plate can produce subsequent deformity. The gunstock varus deformity following a supracondylar fracture is well recognized.

Forearm and wrist

These fractures are generally caused due to indirect trauma from a fall onto the outstretched hand (Fig. 2). All levels of the forearm can be affected, although most fractures occur in the distal third.

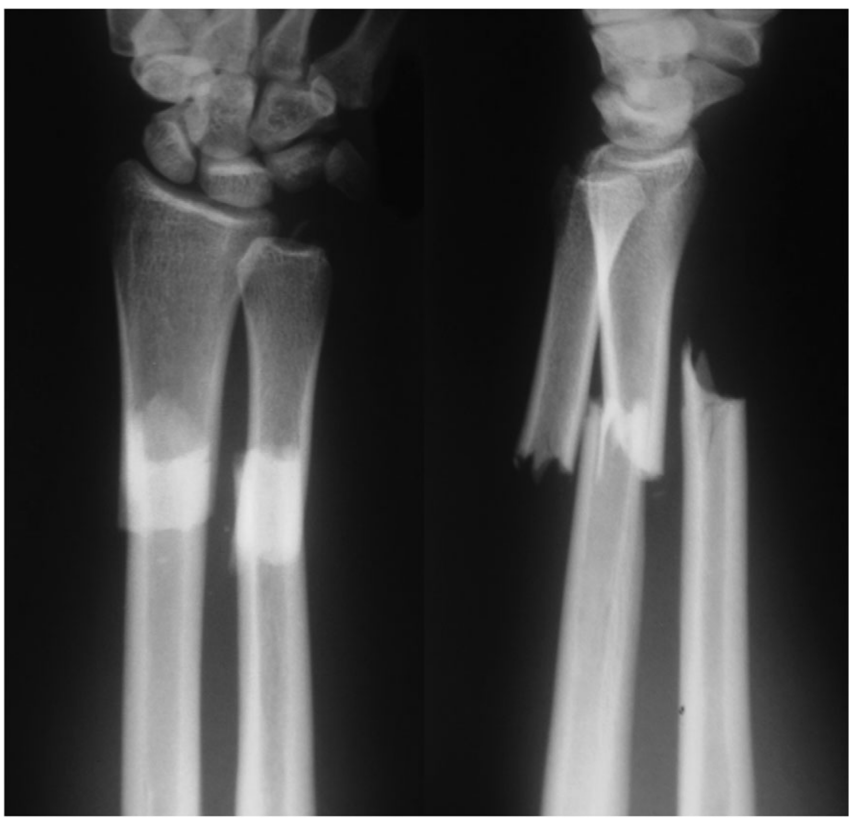

Fig. 2 Radiographs (anteroposterior and lateral view) showing a fracture of the left distal radius and ulna.

Some angulation is acceptable in young children, but angular deformity should be corrected in children >12 years old. Rotational deformity should always be avoided. When either of these factors cannot be corrected by simple manipulation, open reduction and internal fixation should be undertaken.

Tibia

Tibial shaft fractures are the most common fractures that occur during skiing (Fig. 3).[52,53] Management should be conservative for minimally displaced, closed fractures, while, for open or complex fractures, anatomical reduction and stable fixation is necessary.[63,64]

Ankle

The twisting injuries that cause a fracture in adults produce a different pattern of injury in the immature skeleton.[65] In general, ankle fractures in children are minimally displaced. However, when involving the articular surface, they may require open reduction and internal fixation.

Spine

Following trauma, fractures of the cervical spine are less common in children than in adults. Most spinal injuries below the age of 12 years involve the atlanto-axial or atlanto-occipital joints, although all levels are encountered. Prevertebral soft tissue swelling greatly assists

Fig. 3 A distal tibia and fibula fracture (Salter-Harris type 2 injury in tibia, positive Thurston Holland sign) of the left leg.

diagnosis on lateral films. Slight anterior vertebral wedging is normal in children due to incomplete ossification, and up to 2 mm of spondylolysis is acceptable in the upper cervical levels. The high-risk sports for acute spinal injuries are American football, diving, skiing, gymnastics and trampolining. Sporting activities are responsible for between 16 and 27% of all acute cervical spine injuries in children.[66,67]

Epiphyseal injuries

Distal radius

This extremely common injury usually corresponds to the Salter-Harris type 2 classification (Fig. 4). Closed reduction and immobilization are generally sufficient, and results are excellent. A slight dorsal angulation can be accepted, but the young patients must be closely monitored when, in some children, the position is lost and further manipulation is necessary.

Proximal tibia

In the mature skeleton, valgus and varus stress results in tears of the medial collateral ligament (MCL) and lateral collateral ligament (LCL), respectively. In the child, the epiphyseal plate is weaker than the ligaments and gives way instead.[12,28,30,34,68] The knee may be unstable, and plain radiographs may appear normal, but stress

Fig. 4 A Salter-Harris type 2 epiphyseal injury of the left distal radius.

radiographs, taken under anaesthesia if the pain is severe, will reveal the epiphyseal lesion. Treatment consists of immobilization for 4 weeks and controlled mobilization thereafter. These injuries may be very unstable, and some authors recommend percutaneous or internal fixation.

Ankle

Ankle fractures are caused by major violence and frequently result in epiphyseal injury. The most common fractures of the ankle after twisting are type 1 or 2 Salter-Harris injuries with an open distal fibular epiphysis.[12,32,33,69] These fractures often reduce spontaneously, leaving only tenderness over the epiphysis with normal radiographs. Stress radiographs, however, usually reveal the underlying pathology, and, according to the age of the patient, internal fixation should be considered.[12,34,70,71] Tillaux–Chaput fractures are Salter-Harris type 3 fractures of the distal tibia, with an epiphyseal fragment connected to the syndesmosis, and a triplanar fracture is a combination of a Salter-Harris type 2 and type 3 injury. These fractures occur in young athletes close to the end of puberty, due to the orientation of the growth plate, its direction of ossification from posteromedial to anterolateral and the mechanism of injury. These fractures should be treated with internal fixation.[63]

Stress fractures

Stress fractures are difficult to diagnose[57,72,73] and are often associated with training errors.[30,74] Endogenous factors such as body size, sex, diet, hormonal status and anatomical factors are also important, but difficult to prove.[75,76] Stress fractures occur more frequently in women, in particular amenorrhoeic athletes with decreased bone density, and are also more common in organized sports.[48,49,77] Typical locations are the metatarsals (Fig. 5), the middle and proximal tibia, the proximal femur and the calcaneus.[57,63,78] A study of 320 stress fractures reported that 49% of them occur in the tibia, 25% in the tarsal bones and 9% in the metatarsals.[79] Varus alignment seems to play an important role in lower extremity stress fractures. Stress fractures of the navicular are associated with a short first metatarsal, metatarsal adductus, and limited ankle dorsiflexion and subtalar motion.[80]

Diagnosis may be difficult on plain radiographs taken at the time of onset of pain and, therefore, should be repeated after 2–3 weeks. At this stage, however, the rapid periosteal response can be confused with infections or tumours. Magnetic resonance imaging (MRI) or computerized tomography (CT) may be helpful.[81–83] If the clinical picture is

Fig. 5 Stress fractures of the 2nd and 5th metatarsals of right foot.

not typical, a technetium-scan is indicated.[84] Primary management consists of immobilization and reduction of activity to a pain-free level, followed by a gradual increase in activity.[57]

Avulsion fractures

Lesions around the hip

Tendons are relatively stronger than bones. Avulsion fractures occur commonly in the immature skeleton, due to the exertion of sudden intense muscular forces. The anterior inferior iliac spine tends to fail during football when the kicking foot is suddenly blocked, as happens in a tackle. More often, when the foot hits the ground, the anterior inferior iliac spine is pulled off by the reflected head of rectus femoris. In similar circumstances, the psoas muscle can avulse the lesser trochanter. The whole apophyseal plate of the ischium can separate through the powerful pull of the hamstrings. This can happen in cross-country running when the ditch being jumped is wider than expected, and the leading leg is overstretched. More rarely, the anterior superior iliac spine can be avulsed by the action of sartorius in a bad gymnastics vault landing. The whole iliac crest apophysis can also be pulled off by the abdominal muscles, although displacement is uncommon.

Typically, the young athlete gives a history of severe, immediate and well-localized pain, and the appropriate radiographic views confirm the diagnosis. As the avulsions are deep, cryotherapy is unhelpful and oral analgesia is the preferred option for pain relief, with rest and gradual return to activity as pain permits. Immediate surgery is not indicated, and late surgery is rarely required despite occasional dramatic radiographic changes.

Lesions around the knee

A similar imbalance between muscle and ligaments on the one hand and epiphyseal strength on the other has been reported to produce the classical ACL lesion in non-athletic children. In these cases, the ligament itself remains intact, but a large piece of the proximal tibia is avulsed. In 62 young patients with ACL disruptions, avulsions of the tibial spine were found in 80% of children under 12 years old.[85] The mechanism of injury is a flexion, twisting or hyperextension injury, with immediate pain and haemarthrosis. Following radiographs, an arthroscopic washout of the joint is performed, and the intercondylar eminence is fixed back into place using absorbable or non-absorbable sutures.[86,87] Some degree of laxity and lack of full extension is commonly experienced even when anatomical reduction has been achieved.

Epiphyseal growth plate overuse injuries

Olecranon

The epiphyseal growth plate may fail due to repeated microtraumas. Stress fractures through the olecranon epiphysis have been reported in adolescent baseball players, gymnasts and wrestlers.[88] There is pain in the posterior aspect of the elbow with local tenderness over the olecranon and decreased elbow extension. The growth plate is widened. Healing usually takes place with conservative treatment. Occasionally, the epiphyseal plate fails to fuse, and internal fixation is necessary.

Distal radius

Stress-induced changes in the distal radial epiphysis are well recognized in gymnasts.[89] These children present with wrist pain associated with some swelling and local pain on weight bearing and rotation of the wrist. Radiographs show widening of the growth plate with failure of the zone of calcification. With rest, the epiphysis recovers. The prognosis is good, although growth can be interrupted. At the end of growth, the child may present a slight shortening of the radius compared with the ulna.

Apophysitis

Olecranon

This condition occurs at the insertion of the triceps into the olecranon epiphysis in gymnastics, diving, wrestling and hockey. The young athletes complain of local pain and tenderness around the insertion of the triceps tendon, exacerbated by supporting their body weight with the arms. Radiographs may show marked fragmentation of the apophysis. However, they are difficult to interpret because of normal variants in this region. Treatment consists of a period of rest from upper limb activities, and symptoms usually settle over three months. Long-term problems are rare.

Patella

Sinding–Larsen–Johansson lesion is a syndrome of tenderness and radiographic fragmentation localized at the inferior pole of the patella. The lesion can be considered a calcific tendinopathy in an avulsed portion of the patellar tendon and is self-limiting.

Tibial tubercle

A mature tibial tubercle forms from ossification centres in the epiphysis. The pulling action of the patellar tendon may cause inflammation and pain, resulting in the clinical entity known as Osgood–Schlatter lesion. Osgood–Schlatter lesion occurs between 8 and 13 years in girls, and 10 and 15 years in boys. Boys are nearly twice as commonly affected as girls, possibly because of their higher-activity levels. The onset of pain is commonly induced by a higher than normal amount of physical activity. Conservative management is normally sufficient.

Calcaneum

Sever's lesion presents with well-localized, activity-related pain at the tip of the heel and radiographic fragmentation of the calcaneal apophysis. Sever's lesion may result from intensive training and improper footwear.[57] Some authors consider Sever's lesion to be a form of stress fracture. However, there is often a similar radiographic appearance of the other asymptomatic side. The pain responds to rest and a shock absorber under the heel.

Osteochondritis dissecans

Osteochondritis dissecans can be due to intense physical activity causing repetitive microtrauma.[57,90,91] This can be shown by the rate of OCD being three times more prevalent in active boys than girls around puberty, and also in those participating in competitive sports that involve jumping.[63]

Upper limb

Osteochondritis dissecans of the humeral capitellum is well documented, and it can occur in non-sporting children. The dominant arm is affected in little league baseball pitchers, due to valgus loading of the elbow during pitching, so that the lateral side of the joint is repeatedly compressed. In gymnasts, compression and rotation during weight bearing through the arm, and loading of the lateral side of the elbow increased by the physiological valgus of the elbow, affect the joint surface. The youngsters present with elbow pain and some swelling, and are often unable to fully extend the elbow, which is tender over the lateral aspect. Initial signs and symptoms are often minimal. Radiographs are often diagnostic, but early diagnosis may require MRI or CT. The damaged area of the articular epiphysis can break away to form an intra-articular loose body.

If the condition is recognized early, conservative treatment may be successful, with proscription of weight bearing on the upper limbs or of stressing the elbow. Loose bodies should be removed surgically or arthroscopically.[92] Mosaicplasty using an osteochondral autogenous graft should be considered when there is a residual articular surface defect or an incongruous joint to avoid the development of early osteoarthritis.[93]

Osteochondritis dissecans of the radial head is rare. Diagnosis and treatment are along the lines of OCD of the humeral capitellum.

Lower limb

Osteochondritis dissecans usually occurs in the lateral aspect of the medial femoral condyle, femoral head and middle third of the lateral border of the talus.[63,94,95] In general, management is conservative in stable lesions, and with larger fragments, arthroscopic removal of intra-articular loose bodies or fixation is recommended. The long-term prognosis associated with excision of the fragment is poor because of an increased risk of osteoarthritis.[96]

Soft tissue injuries

Muscle injuries

Quadriceps contusions may produce local muscle bleeds associated with injury.[4,12] As in other muscle injuries, the injury may occur from a direct blow, sudden explosive action or occasionally from a more trivial action. Treatment includes rest, ice, compression, elevation and analgesia. Restriction of sport is essential followed by a graduated return to sport. Healing with fibrous tissue, the area may be prone to further injury. Occasionally, a lump is palpable, and, if there are any concerns, MRI is useful to exclude neoplasia.

Chronic compartment syndrome occurs even in young athletes, typically in runners.[97,98] In these patients, compartment pressure monitoring, modification of activity and fasciotomy should be considered.

Tendinopathy

Tendinopathy is a common overuse injury of the lower extremity. Many common forms of tendinopathy can occur in the lower limb. Achilles tendinopathy can arise due to excessive eccentric weight bearing, and tibialis anterior tendinopathy can result from direct pressure in skates or ski boots. In most patients, partial rest and strapping are sufficient. Absolute immobilization leads to musculoskeletal atrophy.[99] Some children will benefit from physiotherapy, especially stretching, and occasionally from peritendinous injections. Surgery is only rarely indicated.

Ankle sprains

Ligaments in youth are considerably more elastic than in adults. Sprains are common, especially in lax individuals, and are normally well tolerated.[31,34,100] Ankle sprains are more common in patients with weak and deconditioned peroneal muscles and pes cavovarus deformity.[34] In general, they should be treated conservatively with the use of orthotics, if the hindfoot is in varus. The first line management in chronic ankle instability should be strengthening and proprioceptive training.[34,97] The prophylactic effect of external stabilization with strapping remains doubtful. There seems to be no beneficial effect of wearing specialist footwear, such as high-top shoes, in preventing ankle sprains in college basketball players.[101]

Ligament injuries

Anterior cruciate ligament tears were considered rare in children, but they are becoming more frequent and are often associated with MCL tears.[102] In one study, 90% of young athletes over the age of 12 years, with anterior cruciate disruptions, were found to have intrasubstance tears.[85] An MRI scan may be performed to ascertain whether an ACL tear has indeed occurred. Although MRI has a good ability to predict ACL disruption, with a specificity of 95% and a sensitivity of 88%, clinical examination is still paramount.[103,104] Conservative treatment of ACL rupture leads to severe instability and poor knee function and carries the risk of sustaining secondary injuries such as meniscal tears.[105–107] However, operative reconstruction of the ACL in skeletally immature patients has the potential to cause growth arrest or result in leg length discrepancy due to physeal damage.[108,109] Complications such as femoral valgus deformity with arrest of the lateral femoral physis, tibial recurvatum with arrest of the tibial tubercle apophysis, genu valgum without arrest and leg length discrepancy have been reported.[110] As a result of this, several authors have advised delayed surgery, allowing time for skeletal maturity prior to reconstructing the ACL.[58,111,112] A retrospective study on 42 children with arthroscopically confirmed ACL disruption showed no significant differences in outcome attributable to patients' chronological age or skeletal maturity.[106] In active children, ACL reconstruction for complete tears resulted in a more stable and functional knee.[106]

Several studies have reported on ACL reconstruction in skeletally immature patients. Soft tissue grafts seem to have no influence on epiphyseal growth.[113,114] Smith and Tao[58] recommend hamstring tendon grafts using central tibial tunnel placement. Lo *et al* found no leg length discrepancy in five patients, aged between 8 and 14 years, who underwent ACL reconstruction.[115] More recently, in a series of 47 knees that underwent ACL reconstruction with a four strand hamstrings graft, no leg length discrepancy or growth arrest occurred.[105] It has been suggested that leg length discrepancies after ACL reconstruction may represent anatomically normal variants.[116,117] Despite this, it is essential that the risks and benefits of ACL reconstruction be analysed prior to surgery in skeletally immature patients.[110,118] Anatomic intra-articular ACL replacements are biomechanically superior to extra-articular and modified physeal-sparing procedures. High-risk prepubescent patients and low-risk pubescent Tanner stage IV patients, nearing skeletal maturity, may be treated with transphyseal reconstruction with small, centrally placed, perpendicular drill holes and quadruple hamstring grafts, with little or no risk of iatrogenic limb length discrepancy.[119]

Medial collateral ligament and LCL injuries are treated non-operatively as in adults. In rare cases, children may sustain tears in the posterolateral corner of the knee, and in such situations surgery is indicated. Injuries of the posterior cruciate ligament, however, can be treated conservatively or operatively after the growth plates have closed.[58]

Back injuries

Scheuermann's disease

Excessive physical stress can be a factor in the development of Scheuermann's disease, which can be diagnosed by a lateral spine radiograph showing three consecutive vertebrae with anterior wedging at least 5°. In addition, the end-plates of the growing vertebra adjacent to the discs are often markedly irregular, and intra-osseous herniation of cartilaginous disc material (Schmorl's nodes) may be a predominant feature. The true natural history of the condition has not been clearly established. Bracing is prescribed to patients with kyphosis between 55° and 80° with promising results. Surgery is suggested only to patients with continued progression of kyphosis, refractory pain, loss of sagittal balance or neurologic deficit.[120]

Spondylolysis and spondylolisthesis

Gymnastics, dance, football, weight-lifting and running are associated with spondylolysis and spondylolisthesis. Spondylolysis is an osseous defect of the pars interarticularis between the superior and inferior facets of the vertebral body. Spondylolisthesis is the slippage of the superior vertebra on the inferior. Both can be related to hyperextension and axial loading, since there is an increased incidence in gymnasts (11%), ballet, fast cricket bowlers and interior linemen in American football.[121] This structural abnormality is not always symptomatic. Although spondylolisthesis can be due to congenitally inadequate superior facets, it is usually acquired. Its frequency increases with age through childhood, especially between 5 and 7 years, to reach 6% in adults. It is thought to be a stress fatigue fracture, although occasionally it is an acute injury. Approximately 70% of spondylolistheses occur at the L5–S1 level, and only rarely occur above L3. They are usually bilateral, but occasionally are unilateral, in which case compensatory hypertrophy of the contralateral pedicle may be seen, as increased density, on plain radiographs. CT clearly shows the defect in the posterior arch and also delineates any foraminal encroachment by bone fragments.

Intervertebral disc prolapse

Adolescent athletes are more prone to intervertebral disc prolapse, although this is a much less frequent cause of lower back pain.[122] The role of continuous bony microtrauma is not clear. On examining a large group of women at least 3 years after retiring from gymnastics, more than half of them showed degenerative changes of the vertebral bodies and of the intervertebral joints. In a study of 70 children undergoing surgery for lumbar disc herniation, 26 routinely participated in sports and 22 of the 70 patients were injured during sports activities.[123] Not all the patients were suffering from back pain, but they all eventually developed sciatica.

The true incidence of disc prolapse in sporting youngsters is unknown, and no definite conclusion can be made. The role of acute trauma as an aetiological factor in the development of disc herniation in young and very young patients has been stressed, but degenerative changes may play a leading role, with trauma acting just as a precipitating factor. A single traumatic episode is not sufficient to produce a disc prolapse unless a degenerative condition is present. This could explain the infrequency of the lesion in children and thence in intensively trained young athletes.

Prevention

The epidemiological approach in sports traumatology aims to quantify the occurrence of sports injuries in relation to who is affected by injuries, where and when these injuries have occurred, and what is their outcome (descriptive approach).[124] Efforts are also made to explain why and how such injuries occur, to develop strategies to limit their occurrence, and to prevent them (analytical approach).[124,125] Preventing sports injuries in young individuals is important to reduce the short- and long-term social and economic consequences.[18] The epidemiological approach implies that injuries do not happen purely by chance.[126]

Most of the preventive measures suggested in the literature have arisen from descriptive research and have not been derived from risk factors that have been substantiated as defensible injury predictors through correlational or experimental research.[125] Not only will children have their own risk factors, but also will their particular sports. There has already been widespread involvement in assessing general risks and trends that result in children's injuries.[43,127–130] Once the analytical evidence points to an association between certain risk factors and injury, thereby establishing a degree of predictability for those participants who are likely to sustain an injury, a method of intervention can be devised for prevention.[131] Intervention can be either therapeutic, using tapes or braces to an injured area resulting in reduction in re-injuries, or preventive, in which an agent or procedure is tried on athletes free from injury and is evaluated by recording the reduction of risk of injury.

Sports-specific studies, for example skiing, baseball, skating, tennis or gymnastics, all have similar conclusions regarding safety barriers or run-offs, adequate supervision, appropriate warm ups and protective equipment.[15,132–138] Many guidelines are already in existence to help limit injuries, as published by Sports Coach UK, for example.[133] In endurance sports, the '10 percent rule', which consists of increasing activity by 10% each week, could probably be applied to prevent overuse injuries.[139] Up to approximately one third of injuries may be preventable. Many of these parallel adult sporting recommendations, are common sense issues. Perceived insight into injury risk has not been reported. Issues specific to children include more fair matching of size, weight and height, appropriate supervision, properly fitting equipment for young individuals and limiting external pressure imposed by parents and coaches. This is a difficult balance to achieve.

The value of preparticipation screening is to limit the participation of the most susceptible individuals and continues to be evaluated.[140,141] Balance, for example, can be used as a predictor of future ankle injury.[140] Prevention is based on defining the fitness and flexibility required, as well as the general medical status. These parameters need to be measured appropriately and advice given to maintain or improve physical status. Preseason conditioning works well to reduce early season injuries.[142] Well-reported successful cases of injury prevention have followed a number of important working parties. Perhaps, the most well known include reduction in the rates of quadriplegia following the banning of spearing in American football, the use of appropriate head and face guards in ice hockey, breakaway bases in baseball,[143] appropriate ball selection, limiting repetitive actions, for example in throwing and bowling sports, and appropriate fluid management in hot weather. However, not all such interventions are entirely successful. For example, the use of chest protectors in baseball does give extra protection, but commotio cordis has still been reported.[144]

Conclusion

In general, sports injuries in children and adolescents are limited to mild contusions, sprains and strains. Any sport can cause musculoskeletal injuries, and the specific pattern and location of injuries of each sport should be known by health professionals. Training programmes and performance standards should take into account the biological age of the participants, and their physical and psychological immaturity, more than their chronological age. A deep knowledge of the different aspects of training, including duration, intensity, frequency and recovery, is needed to avoid serious damage to the musculoskeletal system of athletic children.

Physical injury is an inherent risk in sports participation and, to a certain extent, must be considered an inevitable cost of athletic training and competition. However, coaches and parents can minimize the risk of injury by ensuring the proper selection of sporting events, using appropriate equipment, enforcing rules, using safe playing conditions and providing adequate supervision. Although injuries in young athletes are sustained, it is important to balance the negative effects of sports injuries with the many social, psychological and health benefits that a serious commitment to sport brings.[15,12,31,145]

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