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Abstract

Wintersports are popular activities and became in the past 20 years even more popular. The improvement of the equipment makes especially downhill skiing and snowboarding in general safer than in the past century. But due to higher speed and a trend to ride off the ski run courses, injuries itself get more severe. This can result in complex trauma and requires well trained surgeons to plan and perform therapy. The following should give an overview on the prevalence of Trauma in alpine sports and focus on basic injuries of the foot and ankle.

Keywords

Skiing • Wintersports • Alpine • Snowboarding • Pilon fracture • Haglund Exostosis • Weber Classification • Cross country skiing • Sports trauma

Alpine Skiing

Etiology and Pathomechanism

The most frequent injury types in competitive alpine skiing are joint and ligament injuries (44.0%), followed by fractures and bone stress (18.8%), contusions (12.0%) and muscle tendon injuries (10.5%) [1, 2].

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Injuries

Head and Spine

Incidence of craniocerebral injuries (CCI) is equal in recreational and professional skiing and represents 9% of all injuries [1, 3]. In most cases head traumata are CCI of variable severity, within that severe CCI define the mortality rate in skiing accidents. Generally the rate is of CCI declining over the past years, which is a result of increasing usage of helmets [1].

Trauma of the spine is rare and seems to have a correlation towards male gender [1] and high speed. Spine injuries combined with neurologic deficit occur each to one third in the cervical, thoracic and lumbar spine [4].

Upper Extremity

In the beginning of the twenty-first century almost 1/3 of all injuries were located at the upper extremity [5]. The increase is connected to the popularity of carving skis and is associated with different curve radius, higher risk of falls and especially more forward and backward falls [3]. Professional athletes suffer more often from injuries of the thumb and hand. In contrast incidence of shoulder trauma is higher in recreational skiers compared to professionals. Reasons are higher speed and frequent snow contact [2, 3].

Shoulder

Common injuries are lesions of the rotator cuff (24%), anterior glenohumeral instability (22%), acromioclavicular instability (20%), fractures of clavicle (11%), proximal humerus and tuberculum majus (10%) [6]. 1/3 of all shoulder dislocations showed also intraarticular fractures [7].

Elbow, Wrist and Hand

More distal, fractures of distal radius, shaft and metacarpalia are common. Typical injury is the skier's thumb, which is a rupture of the ulnar collateral ligament or osseous rupture of the metacarpophalangeal (MCP) joint of the thumb and is the most common injury of the hand in skiing (62%) [8]. Injury mechanism is an atypical abduction in the MCP joint while holding a ski pole in case of fall. In severe cases the result is a Stener lesion with a dislocation of the distal ulnar collateral complex and interposition of the adductoraponeurosis [9].

Lower Extremity

Due to the switch to buckled skiing boots in the 70s, location of injuries shifted from the ankle and distal leg towards the knee. Since then incidence of knee trauma is stable. In most of the cases capsula, meniscus and ligament lesions, especially ACL ruptures and medial collateral ligament lesions, occur. [10, 11].

Injuries of the knee

Traumata of the knee are the most common in alpine sports. There is a gender difference where women suffer 3.3 times more likely from a ACL rupture than men [12, 13]. Reasons are anatomical differences (e.g. valgus alignment, smaller notch width), neuromuscular (insufficient quadriceps-hamstring coactivation) and gender specific joint laxity [14].

In recreational skiing ACL lesions happen because of a forward fall with a sudden "catch", while professional skiers incur a "slip-catch-mechanism" [15]. Additionally, concerning recreational athletes, in 96% of the patients with an ACL rupture ski binding was not released correctly [16]. Beside isolated ligament trauma, combined injuries occur. Multiligament- and also meniscal or even osteochondral lesions appear. The unhappy triad is quite rare [17].

Lower Leg and Ankle

Beside soft tissue injuries, fractures of the tibia and the lower leg are typical in recreational and professional skiing. 62% of the fractures in recreational Skiing happen through rotational trauma while 59% of the cases are caused by a malfunction of the release mechanism of the binding [18]. The ski then acts as a lever arm. Professional skiers suffer more frequent of transvers and oblique fractures of the lower leg, especially at the edge of the skiing boot (boot-top-fractures) [19].

Small Breaches

Blisters occur frequently, especially in active populations. It is a result from frictional forces that mechanically separate

epidermal cells at level of the stratum spinosum. Clinical experience suggests draining intact blisters and maintaining the blister roof. This results in the least discomfort to the patient and may reduce the possibility of secondary infection. Treating derroofed blisters with hydrocolloid dressings provides pain relief and may allow patients to continue physical activity if necessary. There is no evidence that antibiotics influence blister healing [20]. The best treatment is to prevent blisters. Blisters can be prevented by wearing properly sized boots, conditioning feet, wearing socks that reduce friction and moisture [21].

Heel Injuries

In essence there are three afflictions about the ankle that result from skiing: rupture of the Achilles tendon, Achilles tendinitis, and dislocation of the peroneal tendon. The cause of Achilles tendinitis and Achilles tendon rupture is, in fact, pressure within the fascial compartment of the Achilles tendon, which is caused by a swollen distal soleus muscle, occluding the circulation and thereby producing avascular necrosis with subsequent tendinitis yielding to rupture [22]. Treatment of tendinitis should be conservatively. In case of Achilles Tendon rupture operative therapy should be preferred to gain optimal stability and lower rerupture risk.

Posterior heel pain can also be attributed to a Haglund deformity, a prominence of the calcaneus that may cause bursa inflammation between the calcaneus and Achilles tendon [23]. Extracorporeal shockwave therapy seems effective in patients with non-calcified insertional achilles tendinopathy. Although eccentric exercises resulted in a decrease in VAS score, full range of motion eccentric exercises shows a low patient satisfaction compared to floor level exercises and other conservative treatment modalities [24].

Distal Fibula Fractures

Fibula fractures should be diagnosed quickly and depending on the findings, treatment needs to be determined whether nonoperative or operative therapy is required [25]. To classify these fractures the Weber or AO classification is used. In snowboarding nearly two-thirds of fractures are to the left limb whereas in skiers laterality is not typical. Most fractures in skiers are the result of falls while a greater proportion of snowboarders have jump-related injuries [26].

Tibial Pilon Fractures

Complicated injuries are tibial pilon fractures. Typical is a rotational trauma leading to spiroid fractures (AO 43-C) associated with joint separation and modest articular and soft tissue damage. Open fractures from inside-out can occur. The elementary separations include the anterolateral pedicle bone on the anterior tibiofibular ligament (Chaput fracture), posterior the Volkmann fragment and medial. In a first step these injuries need to be stabilized, most often using an external fixation to restore the length and prepare for definitive fixation

by plating. Goal of the definitive treatment should be restoring the articular surface to prevent secondary joint degeneration best possible and avoid malpositioning of the foot. [27].

Others

In contrast to lower leg fractures, femur or hip lesions are rare and a consequence of high-speed trauma or collisions [28]. Similar accidents can also cause blunt abdominal-, torso- and thoracic-trauma without involvement of the spine and occur isolated or combined with polytrauma with high “injury severity score” (ISS) [29].

Epidemiology

Competitive Alpine Skiing

Competitive Alpine Skiing is considered a sport with high injury rates. Every third athlete is injured each season and every sixth athlete suffers from an injury that leads to an absence from training and competition for more than 28 days [2]. In contrast to most other sports alpine skiing has a high proportion of time-loss and severe injuries [1, 2]. Males have a 1.24–1.42 higher relative injury risk than females. Ankle, foot and lower leg injury rate was also lower for females compared to males [30].

In competitive (World Cup) alpine skiing the most frequently injured body part is the knee (35.6–36.0 % of all injuries), followed by the lower leg and achilles tendon (11.1–11.5 %), the lower back region (11.1–11.5 %), hand (8.9–9.0 %), head and face (8.5–8.6 %) and shoulder (6.8–6.9 %). The ankle follows next with 5.2–5.3 %. Lower leg, foot, heel and toe injuries account for 1.6 % of all injuries [1, 2].

Injury types to the lower leg are fractures and bone stress (36.4 %), joint and ligament injuries (9.1 %), muscle and tendon injuries (9.1 %) and contusions (36.4 %). Injury types to the ankle are fractures or bone stress (30.0 %) joint and ligament injuries (70.0 %) [2].

Generally it has been observed that high-speed disciplines have a 3 times higher risk of injury compared to e.g. slalom [1].

Recreational Alpine Skiing

Similar to competitive alpine skiing also recreational alpine skiing suffers from high injury risk compared to other sports [31]. Generally a reduction of injuries occurred in recreational alpine skiing in the past years compared to the reference season 1978/1980 [32]. This is due to more use of protection equipment, popularity of Carving skis and advanced slope preparation. 0.84/1000 alpine athletes, is the lowest incidence of inpatient treatments ever recorded in Germany. Reasons are a trend towards ambulant treatment, but can be interpreted as a lower severity of injuries [3].

In detail injuries of the knee joint are by far the most frequently with 37.2 % followed by shoulder injuries 20.1 %.

Head trauma occurs by 7.2 %. Findings of the past years showed a decrease of knee trauma and other body parts in contrast to upper extremity and shoulder [3]. Particular importance is the drop of craniocerebral injury as a result of acceptance of helmets.

Professional athletes have a risk of injury 4.1 per 1000 ski days in contrast to 1.1–3.2/1000 ski days in recreational riders, which is a two to three times higher risk [1].

Therapy (On the Field, Conservative, Surgical)

Alpine skiing is a high-risk sport. Therefore a regional adapted rescue concept is required. If severity of injuries determines to continue the ride, treatment starts direct on the slope by specially trained paramedics. In cases of a life-threatening trauma or impossible to transport the patient on a sledge rescue is usually done by snow groomer or helicopter. In larger skiing areas hospitals for primary health care with radiologic facilities and trained specialists are able to diagnose and precise treatment. Therapy is depending on the injury. Smaller trauma can be treated ambulant while more severe cases need inpatient care. Fractures are handled conservative or if diagnosis requires an operation a definitive osteosynthesis or installation of a fixateur externe is performed. Rehabilitation and aftercare is done by the primary hospital and regional rehab centers itself or in case of tourists in their home countries. Due to limited availability of medical specialists in remote areas some patient need to be transferred to bigger hospitals to get the optimal treatment (e.g. intracerebral bleeding, intensive care monitoring, spine injuries with neurologic symptoms).

Rehabilitation and Back-to-Sports

In general rehabilitation is based on the injury and its required treatment. Smaller trauma normally needs no specific aftercare beside enough rest to overcome the symptoms. More severe trauma needs longer after treatment. In situation with complex fractures or ligament lesions sometimes even stationary rehabilitation including daily physiotherapy is necessary. Regular clinical checkups should be performed by either a GP or a specialist to decide when the patient is ready to be back to sports. In professional sports the priority goal is to be back in training and/or competition. Therefore intensive physiotherapy, adaption of the training and competition schedule is mandatory. The moment of recovery is normally determined by a team doctor in consultation with the coaches, physiotherapists and of course the athlete. Important is to prevent a too early intensive load to avoid relapse or longer drop out especially during a season.

Prevention

Due to the high injury risk in competitive alpine skiing, the International Ski Federation (FIS) has installed a permanent injury surveillance system [1, 2, 30, 33]. Accidents happen as a result of external (weather, snow condition, slope preparation) and internal factors (fitness level, skills) [34]. Specific training especially force in extensions and flexion of the lower extremity, core strength and technique to avoid lay-back position reduce the risk of injury. Another important role is the right choice for a suitable boot and binding combination [35].

In the past years more and more protective equipment found its way to the market and on the slopes. Their mechanism is based on passive stabilization and mechanical protections [32]. There is a variety of braces, vests and suits for ankle, knee and spine. Helmets gained acceptance throughout alpine sports. In professional disciplines is the use obliged [36] while in recreational skiing over 60% of the athletes protect themselves [37]. Helmets prevent or moderate head trauma between 22 and 60% [37–39].

The above section includes evidence level II.

Summary

Alpine sports have a high risk to suffer injuries. The knee (fractures-, ligament injuries) is the most frequent affected body part. In the past years incidence of trauma that required medical treatment was reduced. Increasing numbers of athletes use protective helmets. Therapy is due to the injury and should be performed as soon as possible and with the goal of an early functional treatment.

Snowboarding

Etiology, Pathomechanism and Therapy

Causes of foot and ankle injuries are most likely falls or a result from jumps. There is no significant correlation between boot type (soft, hybrid, or hard) and overall foot or ankle injury rate. But there are significantly fewer ankle sprains in patients wearing hybrid boots and fewer fractures of the lateral process of the talus in patients wearing soft boots [40]. In total snowboarding has a higher incidence of injuries than downhill skiing [41].

Fracture of the Processus Lateralis Tali

Many of these fractures are not visible on plain radiographs and require computed tomography (CT) imaging to be diagnosed. The physician should be very suspicious of anterolateral ankle pain in the snowboarder, where subtle fractures that

may require surgical intervention can be confused with anterior talofibular ligament sprains [40]. As the axial-loaded dorsiflexed foot becomes externally rotated and/or everted, fracture of the lateral process of the talus occurs. Primary surgical treatment may improve the outcome of this injury, reducing the risk of secondary subtalar joint osteoarthritis. In type II fractures, primary surgical treatment has led to achieving better outcomes, reducing sequelae, and allowing patients to regain the same sports activity level as before injury [42].

Peroneal Tendon Injuries

Acute tears of the peroneus brevis, and less commonly the peroneus longus are often coexistent with peroneal instability. Subluxation typically occurs when the foot is in a dorsiflexed position and the peroneal muscles strongly contract, causing an eversion force simultaneously [43]. Most acute peroneus brevis tears are longitudinal, occur adjacent to the tip of the fibula and require surgical treatment. Acute peroneus longus tears more commonly occur at the level of the cuboid tunnel and may initially be managed nonoperatively. However, if associated with stenosing tendonitis, debridement and tenodesis may be required. Rarely, complete ruptures of both peronei occur and, if there is a significant defect, reconstructive procedures are required [44]. Techniques involves suturing using anchors, hamstring allograft reconstruction, the silicone rod technique, flexor digitorum longus transfer to the peroneus brevis, and treatment of associated pathology [43].

Fractures of the Foot

Fractures of the foot are rare in alpine sports. Depending on the radiologic diagnosis treatment needs to be determined. Often CT scans are required to identify a fracture. Operative treatment should be performed in consideration of a wise soft tissue management.

Epidemiology

A study from 12 Colorado ski resorts showed in total 3213 snowboarding injuries, 491 (15.3%) were ankle injuries and 58 (1.8%) were foot injuries. Ankle injuries included 216 (44%) fractures and 255 (52%) sprains. Thirty-three (57%) of the foot injuries were fractures and 16 (28%) were sprains. The remaining injuries were soft tissue injuries, contusions, or abrasions. An unexpectedly high number of fractures of the lateral process of the talus were noted. These fractures represented 2.3% of all snowboarding injuries, 15% of all ankle injuries, and 34% of the ankle fractures [40].

Similar to alpine downhill skiing injury patterns are different in competitive and recreational snowboarding. Elite-level snowboarders are often injured when performing difficult manoeuvres at high velocities and with amplified levels of

force to the lower limbs. Consequently, elite-level snowboarders suffer from injuries that are of higher severity and have decidedly greater lower extremity injury rates [45]. The risk of injuries is higher in snowboard cross than in halfpipe, big air and parallel slalom [46]. Compared to skiing foot or ankle injuries occur more likely with snowboarding [47].

Therapy and Rehabilitation

Please refer section Rehabilitation and Back-to-Sports in the “Alpine Skiing” chapter.

Cross-Country Skiing

Injuries

The majority of injuries in cross-country skiing are overuse injuries compared to traumatology injuries [48, 49]. The types of injuries in competitive cross country skiing consist of muscle and tendon (37.5%), joint and ligament injuries (31.3%), contusions (14.6%), injuries of the nervous system (6.3), skin injuries (2.1%) and others [1]. The incidence is 0.2 injuries per 1000 km skied. All in all cross-country skiing has a low injury risk, especially when compared to alpine slalom, representing the alpine discipline with the lowest risk [50].

Etiology and Pathomechanism

Most of the injuries in professional cross-country skiing are overuse ailment while 25% are caused by trauma. Most common is the medial tibial stress syndrome, achilles tendon problems and lower back pain especially in the age group between 16 and 20 years. Among traumatic injuries most frequently are ankle lesions (ligament and fractures), muscle ruptures and knee ligament sprains.

Shoulder dislocation, acromioclavicular separation, and rotator cuff tears are not infrequent. Lesions of the ulnar collateral ligament at the MCP (Stener’s lesion) is the most common injury of the upper extremity.

Back pain may result from repetitive hyperextension during the kick phase and recurring spinal flexion and extension during double poling phase.

Microtrauma in the musculotendinous units of the groin can be caused by repeated slipping on hard icy tracks. Tears of the medial collateral ligament and the anterior cruciate ligament (ACL) are typical injuries in falls and usually need surgical treatment and long rehabilitation. A twisting mechanism can conduct to a lateral patella dislocation, along with patella fractures and prepatellar bursitis through direct

trauma. Patellofemoral pain is a frequent problem especially on tracks with downhills because increased knee flexion angle requires greater force generated by the quadriceps muscles, which turns into greater stress between the patella and the femur.

Medial-tibial stress syndrome frequently occurs along the medial border of the tibia of professional skiers. Also an anterior compartment syndrome is observed especially in prolonged episodes of the skating technique.

Cross-country skiers also suffer frequently from achilles tendon problems and stress fractures in the foot [48].

Epidemiology

Compared to competitive alpine skiing, cross country skiing has a much lower injury risk. For competitive cross country skiing 11.4 athletes per 100 athletes suffer an injury each season compared to 36.7 in competitive alpine skiing. The number of injuries which lead to absence from training and competition for more than 1 day is 6.3 compared to 29.8 in alpine skiing. 0.7 athletes in cross country skiing suffer a severe injury per season compared to 11.3 in alpine skiing [1]. Expressed in injuries per skiing day cross country skiers suffer an injury at 0.2 to 0.5 to 0.73 injuries per 1000 skiing days [48, 51].

The most frequently injured body part in competitive cross country skiing is the lower back, pelvis and sacrum (26.0% of all injuries), followed by the shoulder and clavícula (14.6%), lower leg and achilles tendon (10.4%), knee (8.3%) and elbow (8.3%), hip (6.3%) and ankle (6.3%). Foot, heel and toe injuries account for 4.2% of all injuries [1]. Beginners seem to be prone for upper body injuries [52]. Cross country skiing athletes suffer a large part of the acute injuries while executing sports other than cross country skiing [51].

Focus: Lower Leg and Ankle

The most common overuse injuries include medial-tibial stress syndrome, arthritic changes in the great toe [53] and achilles tendon problems. Most common among traumatic injuries are ankle ligament sprains, fractures and muscle ruptures [48].

The early functional treatment of acute ankle sprains will return many skiers to activity quickly [54]. Dysfunction of the posterior tibial tendon or rupture of the peroneal tendons is rare, and dislocation cannot be diagnosed with certainty unless it is seen promptly or can be reproduced on examination. Most injuries in cross country skiing can be treated conservatively, and some can be avoided with adequate preparation and training [53]. Fractures, complex ligament ruptures and instability disorders usually need operative treatment.

A severe and often misdiagnosed injury is a lesion of the syndesmosis. External rotation and excessive dorsiflexion of the foot on the leg have been reported as the most common mechanisms. Early rigid immobilization and pain relief strategies, followed by strengthening and balance training are recommended. Heel lift and posterior splint intervention can be used to avoid separation of the distal syndesmosis induced by excessive dorsiflexion of the ankle joint. Surgical intervention is an option when a complete tear of the syndesmotic ligaments is present or when fractures are observed. Indication for a surgical intervention is also given by a rupture of the deltoid ligament, being an important part of maintaining medial stability to the ankle joint [55].

Therapy

On the field medical services should be carried out in the manner of paramedics and in adaption to the situation. In professional sport involve the team doctor or physiotherapist. Sometimes competitions or training take place in remote areas, organize transportation and advanced medical help as soon as possible. Depending on the diagnosis a conservative or invasive treatment should be initiated. Surgical treatment includes osteosynthesis in alignment to the AO criteria and latest operational techniques e.g. in ACL reconstruction.

Rehabilitation and Back-to-Sports

See section rehabilitation and back to sport in the alpine skiing chapter.

Prevention

In recreational sports each athlete should be aware of their own skills and physical shape and adapt the sport load. Also equipment should be checked regularly and be prepared for outside conditions. In professional cross-country skiing taping and other symptoms preventions method are a mandatory part of the training and pre competition preparation. Also testing of the right equipment and sometime even custom made solutions are necessary.

Highest level of evidence in the above section is 3.

Summary

Cross-country skiing is in recreational as well as in professional matter a low risk sport. Most problems occur in terms of an overuse (lower back pain, ventral knee pain, ankle sprains). Traumatic injuries a mostly caused by falls and can

lead into fractures and severe ligament injuries. Prevention involves adequate equipment and sport load in consideration of the individual physical performance.

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