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COVER PAGE

Injuries in Downhill (Alpine) Skiing

"The only sport more dangerous than skiing is sky-diving – if parachute does not open."

Robert J. Johnson

With Janica and Ivica Kostelić (see cover page), Croatia, a small country with no Alps or Dolomites, has become a world power in Alpine skiing. It is one of the rare non-alpine countries where skiing is a very popular sport and where a proportion of population that ski is quite high (1). Skiing has a long tradition in Croatia. Organized skiing has been flourishing in Zagreb, Rijeka, and Gorski Kotar for over 100 years. As a form of recreation, skiing has enormous beneficial effect on psychosomatic health of every individual, irrespective of age, but also carries high risk of serious injuries.

The quote at the beginning of this article belongs to an American orthopedic surgeon and sports traumatologist, R. J. Johnson, who said it at a meeting on surgical management of ski injuries. Downhill skiing can cause injury to any anatomical location, from head to toe.

Head injuries in downhill skiing are usually the most serious injuries in this sport and can be fatal. Such injuries most often result from a collision with a hard obstacle rather than the fall itself. In the USA, 20-30 skiing-related fatalities occur every year, which is 0.5 deaths per 1 million skiers; 60% of those deaths are due to head injuries (2). With brain and internal organ injuries as causes of death, they make 93% of all deaths. Head injuries occur relatively frequently in younger skiers. In Norway, the most common injury (18%) in 15-19 year-old recreational skiers involved the head injury (3). Injuries of the neck and cervical spine are most frequently combined with head injuries. Stanley et al (4) reported 0.49 neck injuries per 100,000 skiers a day in Canada. In the same population, there are 0.74 thorax injuries, which most frequently occur in experienced middle-aged skiers as a result of a clash with some kind of obstacle. Abdominal and pelvic injuries also usually result from a heavy fall or crash. During a 10-year follow-up, Machida et al (5) found abdominal injuries in 1.2% patients with snowboarding-related injuries and 0.7% patients with skiing-related injuries. The main organs involved were the kidney, liver, and spleen. The incidence of solitary renal injury in snowboarding was significantly higher than that in skiing (68.4% vs 29.7%, respectively).

Upper limb injuries are getting more frequent in comparison with those of the lower limb. Due to improvements in ski gear (skies, ski shoes, and ski bindings) and ski slope grooming, the incidence of lower limb injuries has decreased, especially in ankle and lower leg injuries (except the knee), whereas the incidence of upper limb injuries has increased. This is also a consequence of higher speed and greater number of falls and crashes (on usually overcrowded ski slopes). Upper limb injuries account for 20-35% of all injuries that occur in alpine skiing today and nearly 50% of all injuries in snowboarding (6).

Shoulder injuries account for 4-11% of all alpine skiing injuries and 22-41% of upper extremity injuries. The rate of shoulder injuries during alpine skiing is 0.2-0.5 injuries per 1,000 skier-days. Falls are the most common mechanism of shoulder injury, in addition to pole planting during skiing. Common shoulder injuries in skiing are glenohumeral instability or luxation, rotator cuff strains, acromioclavicular separations (luxation), and clavicle fractures. Less common shoulder injuries include greater tuberosity fractures, trapezius strains, proximal humerus fractures, biceps strains, glenoid fractures, scapula fractures, humeral head fractures, sternoclavicular separations, acromion fractures, and biceps tendon dislocations. Elbow injuries, such as fractures or joint dislocations, are possible but not characteristic ski injuries. On the other hand, typical injury of the hand and hand bones and joints in skiers is the so-called "skier's thumb". Thumb injuries usually occur when a skier falls while still clutching the ski pole, which becomes an immovable object. The characteristic injuries are injury to proximal phalanx or metacarpophalangeal joint of the thumb, dislocation of metacarpophalangeal joint or the base of the 1st metacarpal bone, and fracture dislocation of the base of the 1st metacarpal bone (Bennett's fracture). Fractures of the forearm, including Colles' fracture (the lower fragment of the distal radius is displaced dorsally) may also be caused by a fall on an outstretched hand (7). Arm injuries are particularly common on artificial ski slopes, such as those in Great Britain. On this type of slopes, there is a higher ratio of arm to leg injuries (4.2:1.0), with thumb injuries accounting for up to 32% of all injuries (8).

The lower limb ski injuries involve primarily three sites: the knee, lower leg, and ankle. Ski injuries to the lower limb have changed in character and frequency over the recent years. Some types of injuries, very common in the past, have now become very rare, and other injuries are more frequent than before. This change in injury pattern has been caused primarily by the recent innovations in ski equipment. The injury traditionally referred to as the "ski fracture" is a fracture of the lateral (fibular) malleolus, but this term is no longer appropriate. The incidence of this type of injury has decreased dramatically over the last 15 years as more and more skiers wear the new type of boot. Unfortunately, epidemiological studies have shown that knee injuries, particularly the so-called soft-tissue knee injuries involving menisci and ligaments of the knee, have become more frequent in the last 18 years, showing a two-fold increase (9,10). The grade III knee sprains (rupture) have increased from 17% to 73% of all knee sprains over the last 18 years (10). Currently, serious knee sprains represent a larger proportion of injuries than any other group of soft tissue injuries, and even larger than fractures.

The most severe type of fractures occurring in skiers are fractures of the tibia and fibula. Under a relatively slight force, minimal displacement of the bones occurs; the tibia is fractured at the junction of the middle and distal thirds, and the fibula often in the proximal third. If the external rotation-abduction force is great, the result is a serious comminution fracture. Other types of fractures in skiing, which occur less frequently than tibial and fibular fractures, are the fracture of the lateral malleolus, fracture of medial malleolus, bimalleolar fracture, and trimalleolar fracture. The incidence of these "intraboot" fractures is decreasing, as more skiers wear modern boots. Femoral fractures are also rare. The femur may be fractured by a direct fall on a hard frozen surface, and such injury usually involves the trochanteric area. If the skier falls on a hard surface of frozen snow or ice while skiing downhill, the trochanter facing the uphill side may be severely contused. The consequence is a large hematoma. More rarely, the fall will cause trochanteric avulsion or fracture. The incidence of femoral neck fractures, which is low, may increase with age of a skier. Femoral shaft fractures are almost invariably the result of collision accidents. Lower extremity can suffer some rarer types of injury, which are difficult to recognize on X-ray examination. Isolated boot-top fracture of the fibula may be difficult to diagnose immediately, because initial X-ray examination may not reveal any fracture. However, periosteal change will be obvious on a subsequent roentgenogram. Although epiphyseal separations of the distal fibula occur less frequently today than in the past, they could be difficult to diagnose because X-rays often show no apparent abnormality. Among soft tissue injuries of the leg, the incidence of Achilles tendon ruptures is increasing as more skiers wear higher ski boots. The severe force of a forward fall when directed to the cross-sectional diameter of the stronger proximal tibia may result in partial or complete rupture of the Achilles tendon.

While the overall incidence of lower extremity injuries has decreased, the incidence of severe knee injuries (grade III knee sprains, involving the anterior cruciate ligament) is on the rise (10-12). The presently available ski equipment does not provide the same protection to the knee as to the rest of the lower extremity. Skiers sustaining anterior cruciate ligament injuries are older, heavier, more often female (13), and they have more experience than other skier age groups. These skiers use state-of-the-art bindings and boots. External rotation associated with abduction is the force responsible for most grade III knee sprains, which can be divided into mild and severe grade III sprains. In mild grade III sprain, tear of the middle third of medial capsular ligament occurs and (medial) tibial collateral ligament is partially or completely disrupted or avulsed. A gap in a joint capsule may minimize effusion by permitting the leakage of fluid. In severe grade III sprain, the anterior cruciate ligament is torn, tibial collateral ligament completely ruptured or avulsed from tibia. Also, meniscotibial and/or meniscofemoral ligament is torn, permitting a "floating" of the medial meniscus. The posterior cruciate ligament may be torn. The lateral compartment usually remains intact but may be partially torn. Severe grade III sprain leads to great instability and disability of the knee and demands careful and thorough examination: X-rays, sonography, magnetic resonance imaging (MRI), and arthroscopy. The procedure for knee examination must follow a logical, step-by-step course and must include careful recording of all findings so that any change in the condition is immediately recognized (14). Physical examination, including specific testing and X-rays, is always the first step. It would be a mistake to refer a patient to MRI without knowing what one is searching for. The decision on the type of treatment is made on the basis of complete diagnostic evaluation of the patient, where MRI is of invaluable use (Fig. 1). In the case of severe grade III sprain, the treatment is exclusively surgical, including full arthroscopic procedure or assisted arthroscopic procedure for the reconstruction of all anatomic structures. The results of operative treatment are very good. Of course, we must not forget rehabilitation, which takes the same credit in recovery of the patient by use of special orhtoses and isokinetic instruments.

However, as always, prevention is more important than the treatment of injuries. It is commonly agreed that the development and use of modern ski equipment, especially release bindings and plastic ski boots, has contributed to the decline in the incidence of injuries in downhill skiing (15). All investigations show a pronounced decline in the incidence of the lower extremity injuries to approximately 50% of the incidence 15-20 years ago. Also, by using a ski pole specifically designed to prevent the thumb from being inserted to the snow during a fall, the frequency of skier's thumb was reduced from 4.0% to 2.8%. While the overall incidence of lower extremity injuries has decreased, the frequency of severe knee injuries continues to rise. The ski equipment presently available cannot provide the same protection to the knee as it does for the rest of the lower extremity. Ettlinger and

Figure 1. Magnetic resonance image of the knee injury. **A.** Sagittal fast spin echo T2 fet suppressed image: rupture of the anterior cruciate ligament (arrow) in proximal insertion of the ligament. **B.** Coronal short tau inversion recovery image: rupture and contraction of the medial collateral ligament (arrow) and bone contusion (small arrow). **C.** Sagittal gradient echo T2* image shows rupture in the posterior horn of the medial meniscus (arrow). (Courtesy of Dr. Igor Borić, MR Unit, "Neuron" Polyclinic, Zagreb, Croatia).

Johnson (16) suggested a fall-training program as a solution to the problem of knee injuries and anterior cruciate ligament tears in particular. However, no specific recommendation can yet be made for an effective injury-prevention program for the knee and anterior cruciate ligament injuries. In recent years, considerable effort has been made to diminish risk factors of the Alpine skiing technique (17). Specific safety prevention measures include information about ski equipment and binding design, standards for the preparation of the slopes, and skier-responsibility codes. Ski resorts now insist on following a basic code of skiing safety rules, which, if infringed, result in ticket revocation. Ski safety campaigns have been launched in many countries. In Sweden, the frequency of ski injuries decreased after a campaign for safer skiing. The injury risk was reported to diminish by almost 20% as a result of the promotion of binding testing alone. Proper binding setting and mounting reduced lower extremity equipment-related injuries by a 3.5 factor, compared with the control group (18). Concerns about whether a new type of ski – the super-sidecut or carving ski – has the potential to significantly alter the incidence and type of ski injuries have arisen in the past 5 years (19,20). The first investigations by Johnson et al (19) reveal that ski injuries associated with super-sidecut skis occurred at a higher rate than expected in comparison with conventional skis.

Recent study (1998-2000) on injuries in Alpine skiing, snowboarding, and telemarking in Norway revealed that already injured skiers were prone to knee injuries, whereas lower leg fractures continued to be most common in children (21). Snowboarders were prone to injuries and fractures of the wrist, and telemark skiers to hand injuries. The percentage of knee injuries in women skiers was twice the percentage of the same injuries in men in all three disciplines. In Alpine skiing, among all injuries, arm injuries accounted for 5%, wrist injuries 4%, hand injuries 9%, knee injuries 28%, fractures (all) 20%, and lower leg fractures for 7% (21).

Injuries in Alpine skiing related to age groups were investigated in a Norwegian study conducted from 1996/97 to 1999/2000 during the 4 winter seasons (22). The head and knees were the main sites of injury in alpine skiing irrespective of age. Within the injured population, fractures wee more common in children than in older age groups. The most common injury sites among the adults were the knee (31%), head (15%), and shoulder (14%) (22).

In conclusion, it seems that Elmqvist's warning from 1994 is still valid (23): "The skier has the ultimate responsibility to educate himself or herself about ski safety measures, to avoid injuries by skiing according to his or her ability, and to adapt to the conditions present on the ski slopes while using well-maintained and reliable ski equipment. There are several important ways of preventing ski injury in downhill skiing. But, regardless of the safeguards provided on the slopes and regardless of the individual efforts made to exercise caution and good sense, downhill skiing will retain its reputation as a high-risk

sport." Taking into consideration a risk-benefit ratio for health, I would recommend Alpine skiing to every individual. But I must also warn all skiers to take every injury very seriously until concluded otherwise by a specialist, usually orthopedic surgeon.

Marko Pećina

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