Skiing (Alpine, Nordic, Road, Track) 27

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27.1 Some Key Elements in the History of Skiing

27.1.1 Skiing: A Necessity and Survival Tool

For more than 10,000 years, the word "ski" has been used in the dialects of many peoples in northern Europe and Asia (skis: suski, suks, sok, suksildae). The first rock engravings showing skis in skis date from 4000 BC and depict men wearing long planks (Fig. 27.1).

These men who lived at altitude after the ice ages and were led in the face of significant snow conditions to develop tools to improve their mobility and their living conditions. Skiing was born in the Nordic countries, especially the peoples who lived between Lake Baikal and Mount Altai. Ski remains to date back more than 4000 years have been found in Norway and also in Scandinavian peat bogs with shorter or shorter fossil skis attesting to a different evolution of the equipment according to the regions.

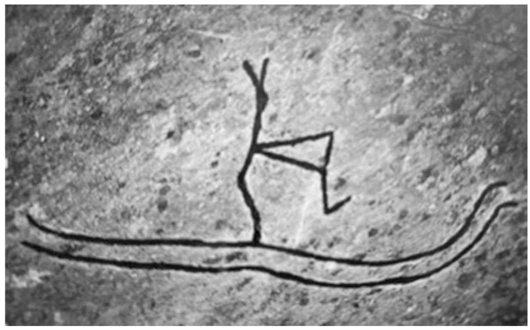

Fig. 27.1 Cave painting showing "man on ski"—4000 BC

From the tenth century, the use of skiing became more popular in Norway and Sweden.

27.1.2 Skiing: A Fast and Silent Means of Mobility Useful for the Military

In 1552, skiing played a decisive role in the uprising organized by Gustav Vasa for the liberation of

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Fig. 27.2 1900: army soldiers help democratize and spread the practice of skiing

Sweden (celebrated every year since 1922 by one of the most important international cross-country ski races: “La Vasaloppet”).

It was at the end of the nineteenth century that the French army became interested in this means of fast and silent transport. The army of the Alps is responsible for monitoring the high valleys. The Ministry of War bases the first military skiers at the Col du Lautaret in 1900, and created in 1904 the first army ski school to train several generations of military skiers. These soldiers, often ski instructors in their spare time, will help democratize and disseminate the practice of skiing to tourists and local mountain populations (Fig. 27.2).

27.2 When Skiing Becomes Leisure and a Sport

In the nineteenth century, the Scandinavians came up with the idea to transform the practice of skiing into a sport. This shift of skiing to sports and leisure activities will be punctuated by developments initiated by men who propose technical modifications to the equipment and also changes to the practice and technical gesture.

Norwegian skis are 3-m long and attached to the feet with a simple strap (Fig. 27.3). Their instructions are rustic:

“Skiers let skis drive them where they want until the air acts as a natural brake and causes them to stop.”

“When going downhill, the skier leans on his pole and closes his eyes. Then he goes straight and continues until he can no longer breathe. He then throws himself on the side in the snow and waits to catch his breath, then he launches straight on until he still loses his breath and throws himself in the snow, and so on to the bottom.”

In 1850, the Norwegians mold the first arched skis: the weight of the skier is better distributed over the snow, and the “gliding” is better.

In 1868: Sondre Norheim manufactures “wasp size” skis with variable dimensions.

The skis are wider in the heel and the tip than under the foot. The turns are easier: placed on the side, the ski follows the curve under the pressure of the skier. On the binding side, it braids a

Fig. 27.3 Norwegian skis were 3 m long

wicker strap that goes behind the heel so that the ski comes back naturally under the foot.

An ultimate and brilliant finding, he developed a turn, which he called telemark: on his knees on the inside ski, the pivoting was obtained by pushing the outside foot in the direction of the curve (Fig. 27.4).

February 9 is the first national ski competition in Iverslokken.

1878: Grenoble mountaineer Henry Duhamel descends with 3 m boards on the slopes of the Croix de Chamrousse near Grenoble and succeeds in one of the first long ski descents.

1882: ash wood, which is most often used for its flexibility and lightness, is replaced by hickory (already imported from Louisiana to make golf clubs) because it allows to cut narrower, more flexible skis while remaining robust.

1889: Mathias Zdarsky invents alpine skiing (Fig. 27.5).

He understands that the skis are too long to face the steep slopes, and he reduces their size from 3 m to 1.80 m, removes the grooves from the sole, and makes a metal stirrup to lock the foot on the ski (he will deposit one hundred and four–twenty fastening patents).

Fig. 27.4 Sondre Norheim invented telemark and wasp-sized skis

Several technical schools compete: the Norwegian school, called "Telemark," that of Lilienfeld, called "Alpine technique," and that "of Christiania" (first parallel turn downstream to embark on big slopes).

1905: Zdarsky, to objectively quantify the difference between these techniques, plants stake on the slope: he has just invented the giant slalom.

1908: Arnold Lunn founded the Alpine ski club, invented timed slalom, downhill events, and created the most prestigious alpine ski competition: the Kandahar.

1928: Rudoph Lettner screws steel blades on each side of the ski and has just invented the metal edges.

This year, the ski lifts appeared in the Alps.

1933: first Rochebrune cable car in Megève.

1934: first ski lift in Davos.

Things are started, skiing becomes an essential economic activity (the white gold rush) and since then has not stopped evolving and democratizing.

Today, all over the world, skiing and snowboarding have become the most practiced winter sports.

Practitioners, whether amateur or professional, are particularly exposed to trauma in the alpine modalities, freestyle skiing and snowboarding, and also to overuse pathologies in the context of Nordic skiing.

Fig. 27.5 Mathias Zdarsky: precursor of alpine skiing

These activities have become more and more accessible, with more and more efficient equipment which allows an ever-increasing number of practitioners to go faster and faster on every larger ski area.

This evolution of practices and equipment has considerably modified the accidentology and traumatic pathology linked to the practice of skiing and snowboarding.

27.3 We Propose to Analyze in this Work

- The current traumatic pathology of a standard population based on an analysis over a period of 60 years, of the activity of a trauma and sports service located "at the foot of the slopes" at the southern hospital of Grenoble.
- The more specific traumatic pathology of high-level skiers from the monitoring of competitors in the French team.

27.4 Accidentology and Traumatic Pathologies Linked to the Practice of Snow Sports in a Standard Population

The trauma of snow sliding sports has evolved considerably over the past 50 years. Before the 1970s, the practice of skiing was relatively confidential, and only a few initiates engaged in this practice. In Alpine skiing, bimalleolar fractures were by far the most frequent fractures. Gradually, new sliding techniques appeared with cross-country skiing at the end of the 1970s, then snowboarding at the end of the 1980s and finally snowblade (short skis, less than 1 m long) at the end of the 1990s. In parallel with this evolution of practices, the equipment has considerably evolved as well as the preparation of the ski area, with an increasingly pronounced craze for this leisure activity. Therefore, the trauma has changed over time. Even if snow sports accidents are currently commonplace, they only represent 2.5 accidents per 1000 ski days which are far behind the seven accidents per 1000 days of the 1970s. Alpine skiing remains by far the most practiced with snowboarding, and we will, therefore, focus on these two disciplines which summarize the major evolution of snow sports over the past 25 years.

Given the significant frequency of ruptures of the anterior cruciate ligament (ACL), we will discuss in a specific chapter, the mechanisms of ACL rupture during alpine skiing.

27.5 Epidemiology, Evolution, Prevention of Downhill Skiing Accidents (from 1968 to 2012)

The epidemiological study is based on the analysis of the activity of the same hospital service at the Grenoble University Hospital, which has documented ski track accidents since 1968 until today. We were, thus, able to compare the evolution of trauma-based on three studies: the first carried out in the 1970s by Professor Bèzes (between 1968 and 1976); the second and the third carried out by Professor Saragaglia in the 1990s on the one hand (between 1990 and 1997), and in the 2010s on the other hand (from the 1998–1999 season to the present day).

27.6 In the Seventies (the Series of Prof H. Bèzes)

The cohort includes 5200 injured people, victims only of a ski accident (no cross-country ski accident recorded at that time), 59% men, and 41% women, average age 22 years (2–77) (Table 27.1).

Table 27.1 Evolution of snow sports accidentology in recreational practice

	1968–1976	1990–1997	1998–1999	2008–2009
Number of patients	5200	4647	731	591
Alpine skiing	5200	3570	567	425
Cross-country skiing	0	322	NC	NC
Snowboard	0	535	134	139
Nordic skiing	0	110	25	26
Artistic skiing	0	86	0	0
Snow blade	0	1	6	1
Monoski	0	19	0	0
Telemark	0	3	0	0
Skwal	0	1	0	0
Alpine Skiing (*N*)	5200	3570	567	425
Male (%)	59	53	58	55
Female (%)	41	47	42	45
Mean age (years)	22	29	30	30
Anatomical site	Injuries (percentage values)			
Body axis	9%	7%	Not included	Not included
Upper limb (%)	15	31	29	35
Scapular girdle (%)	45	37	44	51
Wrist fracture (%)	16	11.4	10	17
Hand (%)	21	29	24	16
Sprain of MCP of the thumb (%/hand)	40	67	72	46
Others (%)	60	33	28	54
Lower limb (%)	76	62	71	65
Femur fracture (%/lower limb)	3.3	8.1	4.2	4.7
Knee (%/lower limb)	18.8	60	60	66
Severe knee sprain (% knee)	10.2	36.2	35	40.5
Tibial plateau fracture (%/knee)	1.2	5	7.1	12.5
Leg fracture (%/lower limb)	57.6	19	25	16.5
Ankle (%/lower limb)	18.5	7.3	5.5	2.2

Group 1 lesions (body axis: head, face, spine, thorax, abdomen, pelvis) represented 9% of all lesions, including 33% of spine lesions and 5.5% of pelvis lesions.

Lesions of the upper limb represented 15% of all lesions including 45% of lesions of the shoulder girdle and 21% of lesions of the hand (40% of sprains of the metacarpophalangeal joint (MCP) of the thumb.

Lesions of the lower limb represented 76% of all lesions with, 57.6% of fractures of the leg, 18.8% of lesions of the knee, 18.5% of lesions of the instep, and 3.3% fractures of the femur.

27.7 In the Nineties (Prof Saragaglia Series)

The cohort included 4647 injured people (4920 injuries) including 3570 alpine skiers (3788 injuries), 535 snowboarders, and 322 cross-country skiers. Among alpine skiers, we had 53% men and 47% women whose average age was 29 (2–84) (Table 27.1).

Group 1 lesions represented 7% of all lesions, including 29% of spine fractures and 20% of pelvic fractures.

Lesions of the upper limb represented 31% of all lesions including 37% of lesions of the shoulder girdle and 29% of lesions of the hand (67% of sprains of the MCP of the thumb).

Lesions of the lower limb represented 62% of all lesions, including 60% of knee lesions, 19% of leg fractures, 8.1% of femur fractures, and 7.3% of instep.

27.8 In the 2000s (Series by Prof Saragaglia)

This series analyzes the epidemiology of alpine skiing and snowboarding accidents 10 years apart by comparing the 1998–1999 and 2008–2009 seasons. Overall, we have seen an increase in serious accidents (fractures, dislocations, severe sprains) going from 62.1% to 71.5% ($p < 0.001$), or from 26.1% of surgical treatments to 36.5% (Table 27.1).

Regarding ski trauma, we have witnessed a “sliding” of the lesions up the body with an increase in damage to the upper limb (from 29% to 35%) knowing that the lower limb remains the most affected. This “sliding” toward the top of the body corresponds to a significant increase in lesions of the wrist ($p = 0.021$), shoulder, and shoulder girdle ($p = 0.036$) (Fig. 27.6). Conversely, sprains of the metacarpophalangeal thumb have decreased significantly ($p = 0.006$). The knee remains the most affected joint, but

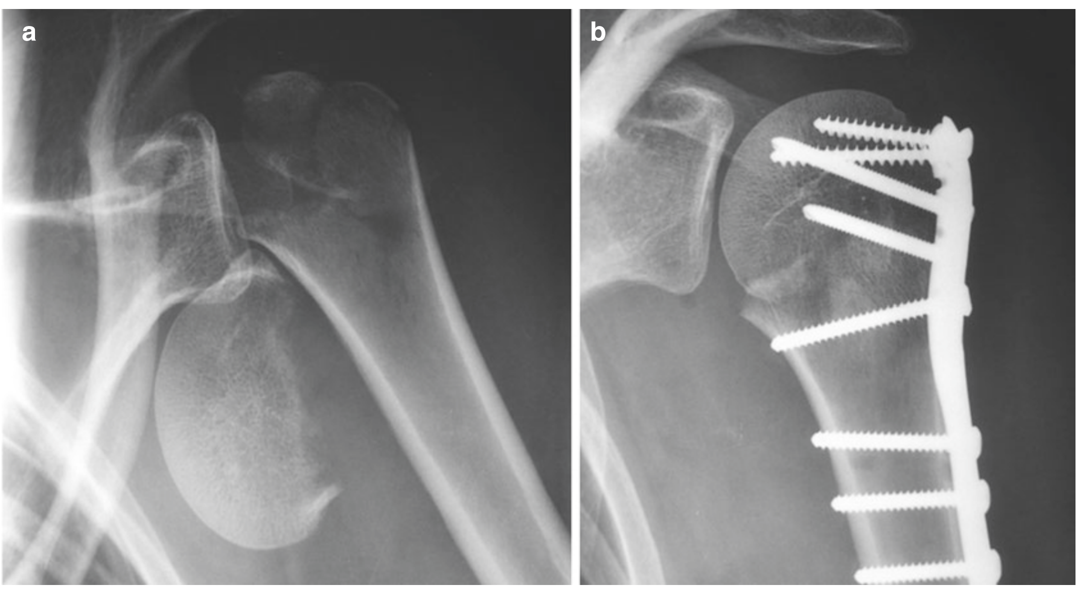

Fig. 27.6 fracture-dislocation of the humeral head (anatomical neck) (**a**) preoperative and (**b**) postoperative X-rays

its proportion remains stable (42.32% in 1998–1999 and 43.06% in 2008–2009) with a majority of ACL lesions. There is indeed a decrease in the proportion of benign sprains ($p = 0.041$) in favor of severe sprains which go from 20.9% to 26.81% of lesions of the lower limb. We will see in the analysis of risk factors that the appearance of parabolic skiing, which constitutes the main technical evolution between the two studied seasons, seems to have a responsibility in alpine skiing trauma modifications.

27.9 Currently

Our database includes 12,352 alpine skiing accidents and 3290 snowboard accidents. Over this period, in alpine skiing, the knee was most frequently injured with 3851 sprains (31.2%) including 235 avulsions of the anterior tibial spines and 496 fractures of the tibial plateau (4%) (Fig. 27.7). Regarding leg fractures, we counted 1199 fractures, or 9.7%. In snowboarding, we counted 669 fractures or epiphyseal detachment of the distal end of the radius (20.5%). These figures, over a long period, corroborate what has been demonstrated elsewhere over shorter periods and with a smaller population.

27.10 Evolution of Accidents

Body axis lesions, despite tending to bend, remain relatively stable over time. The decrease in their frequency, observed in our study, is linked to a recruitment bias since hyper specialization has led us over time to direct the management of these craniocerebral traumas and serious trauma to the spine, to other more specialized structures equipped with dedicated multidisciplinary technical platforms.

On the other hand, the isolated trauma of the limbs has worsened to represent in certain centers and according to the data in the literature up to 25% of recruitment.

Lesions of the upper limb, after a considerable increase was observed between 1976 and 1997 (from 15% to 31%), stabilized slightly above 30% (29% in 1999 and 35% in 2009). However, the distribution of lesions has changed. In fact, there has been an increase in lesions of the shoulder girdle (fractures of the clavicle, shoulder dislocations, acromioclavicular disjunctions), with a rate which

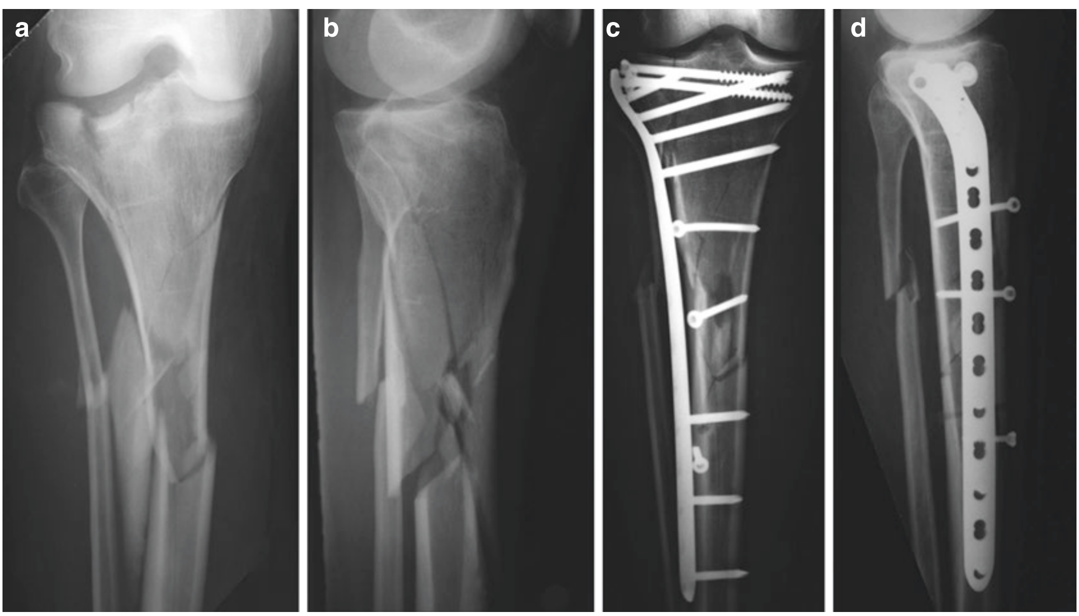

Fig. 27.7 (**a** and **b**) Preoperative AP and lateral radiograph views of complex T-shaped fracture of the tibia plateau and diaphysis. (**c** and **d**) postoperative AP and lateral radiograph views of fracture osteosynthesis

increased from 6.8% in 1976 to 13% in 1999 and 18% in 2009. There has also been an increase in fractures of the lower extremity of the radius, especially in the past 15 years because this rate increased from 2% in 1997 to 3% in 1999 and 6% in 2009. On the other hand, sprains of the MCP of the thumb, after a significant increase between 1976 and 1997 (from 1.3% to 6%), decreased with a rate which rose from 5% in 1999 to 2.5% in 2009.

Lesions of the lower limb stabilized around 65% (71% in 1999 and 65% in 2009) after a significant drop between 1976 and 1997 (from 76% to 61%). The rate of leg fractures stabilized at around 10% (15.5% in 1999 and 9.2% in 2009) after a considerable drop between 1976 and 1997 (from 44% to 11.5%). Knee injuries (mainly sprains and fractures of the tibial plateau) also stabilized around 42% (42.3% in 1999 and 43% in 2009) after a considerable increase between 1976 and 1997 (from 14.5% to 37%). Knee sprains remain the most frequent lesions with 37.2% of sprains in 1999 (including 15% of serious sprains with at least a rupture of the ACL) and 34.6% in 2009 (including 18.2% of severe sprains). The fractures of the tibial plateau were multiplied by 5 between 1976 and 2009 (from 0.2% to 5.3%), and the fractures of the femur were multiplied by 2 (from 2.5% to 5%).

27.11 The Reasons for this Development

Several factors explain this evolution of lesions:

- the evolution of the material,
- the evolution of the ski area,
- frequentation of the slopes.

27.12 The Evolution of the Material (Equipment) Has Changed the Mechanism of Injuries in Alpine Skiing

First of all, the shoe which went from the 1950s boot to the shoe with a high and rigid upper from the 1990s and 2000s (Fig. 27.8).

This development helped move the lesions up the lower limb. Thus, this type of shoe protects the ankle and the leg (reduction of fractures of the instep and the leg), but increases the stresses especially at the knee level, and to a lesser degree at the level of the femur.

Then, the bindings of the boot on the ski are triggered more quickly and in several planes of space, and not in the frontal and sagittal planes. This faster release of the bindings explains

Fig. 27.8 Evolution of ski equipment and boots: from a loose ankle to a blocked ankle

some falls forward, real dives with reception on the stump of the shoulder on groomed snow. Furthermore, improper adjustment of the fasteners contributes to increasing the incidence of ACL tears.

Finally, the ski itself developed from VR7, VR17, Strato in the seventies to parabolic ski to the end of the 1990s (Fig. 27.9).

We can consider that there were few skiers who used these skis during the 1998–1999 season whereas in 2008–2009 this type of ski is widely used since it represents almost all skis today, rentals and new purchased skis. These skis involve a new way of sliding, it is the "carving effect" which is inspired by snowboarding. The principle is based on a spatula and a widened heel while the middle of the ski is narrowed. This curvature will make it possible to decrease the radius of the turn, which is of the order of 45 m with traditional skis and from 10 to 30 m with the "carve" of parabolic skis. This finer handling in cut turns will considerably increase the skier's speed by decreasing the skid. During a "carving" turn, the skier leans as far as possible inside, giving way to a new trauma (closer to that of snowboarding) linked essentially to the stalling of support at high speed. There is, therefore, trauma by direct impact on the shoulder girdle and wrists (fractures). Although it is a more accessible ski for beginners to progress faster and reach high speeds in a short time, this increases the severity of the lesions. This type of skiing *does not spare the knee* (persistence of a majority of ACL lesions) because to drive the turn, the skier must print a movement of valgus external rotation to the knee of the lower limb downstream of the turn, stressing the central pivot. Paradoxically, despite the presence of the wrist strap, there has been a reduction in sprains of the metacarpophalangeal joint of the thumb.

The ski area has evolved considerably over the decades. Today, the ski slopes are wide,

Fig. 27.9 Evolution of bindings and skis: from a free foot and from a straight ski to a held foot and to a carved ski

groomed, often prepared with snow cannons. This leads to an increase in the speed of skiers which has almost doubled in more than 40 years. Falls are more dangerous and more serious as are collisions (between skiers or against a tree or rock). These falls at high speed on snow that looks like concrete, and the modification of practices (free ride with jump of rocky bar) largely explains the increase in serious trauma (fractures-dislocations of the shoulder, complex fractures of the plateau tibial, fractures of the pelvis, fractures of the femoral shaft or the neck of the femur) and polytrauma.

Overcrowded slopes, lack of snow and unsuitable weather conditions further increase the risk of serious accidents.

27.13 Prevention

The prevention of serious accidents involves reducing and harmonizing the speed of skiers. It is also essential to regulate the density and traffic on the ski slopes. The systematic wearing of helmets in children has helped reduce serious head injuries. Finally, the education of skiers must remain essential with the learning of a certain civic spirit and a code of good conduct on the slopes.

The prevention of serious knee sprains requires regular maintenance and adjustment of the bindings. Perhaps we should further improve the multi-directional release of the bindings or develop shoes with rear opening in the event of a backward fall? Finally, educational programs could be of significant help.

27.14 Epidemiology, Evolution, and Prevention of Snowboard Accidents (Snowboard)

Snowboarding traumas represents between 20% and 25% of snow sport accidents. It is marked by a significant upper body involvement that increases over time (from 60.5% to 81.3%—$p < 0.001$). In the foreground, the shoulder and shoulder girdle injuries increased significantly between the 1998–1999 and 2008–2009 seasons, from 14.2% to 31% ($p = 0.002$). The shoulder lesions increased from 4.5% to 13.5% ($p < 0.05$). In our series, the wrist fractures represented the second lesion location, and also increased between 1998–1999 and 2008–2009, going from 17% to 20%.

The involvement of the lower limbs is much less significant in snowboarding and decreases over time since it represented 39.5% of all lesions in 1998–1999 and 18.7% in 2008–2009. We are currently witnessing a significant reduction in knee injuries and more particularly benign sprains since the proportion of involvement of the medial collateral ligament drops from 16.4% to 1.5%. These figures do not agree with the statistics of mountain physicians who find a stability of this type of sprain at around 6.5%. ACL rupture remains rare in snowboarding since it represents only 1.5% of all lesions in our 2008–2009 series and is rather the result of high energy trauma.

In recent years, the evolution of snowboarding equipment has been more progressive, with no major revolution, but rather with a refinement of the technical characteristics of the different types of boards. These have improved by becoming more responsive and faster than before. As its technical development progressed, snowboarding was divided into three main specialties: “free-ride,” “alpine,” and “free-style.” Alpine and competitive surfboards, hard and narrow, with a rounded shape at the front, are precise and fast for surfing on edges. Their proportions have decreased over the past 15 years. This type of board is used with bindings and rigid boots like those used in skiing, which perfectly protect the foot and forefoot. The more flexible free-ride board makes it possible to exploit all the possibilities of the discipline: from off-piste in deep snow to carving on hard tracks. As for jumpers and snow-park enthusiasts, they preferably use a “free-style” board, with more flexible shoes allowing significant back flexion. This type of shoe leads to tearing lesions and fragmented fractures of the lateral tubercle of the talus which are entirely specific to snowboarding (5.6% of lesions of the lower limb in snowboarding in

1998–1999). There are also malleolar fractures (7.7% of lesions of the lower limb in snowboarding in 2008–2009), which are favored by the starting position of the surfer who descends the track in a position of pronounced rotation of the ankles relative to the axis of descent and body.

Regardless of the type of board used, the "carving" effect is used by surfers who are very leaning in turns, with the risk of direct impact on the upper limb, which explains why the upper body is most affected and that rates are still increasing.

Prevention essentially involves educating surfers because the prevention of wrist fractures by protective splints has not been proven to be effective and tend to move fractures up the upper limb.

27.15 Mechanisms and Risk Factors for ACL Tears in Alpine Skiing

Johnson summarizes the ACL rupture mechanisms in skiing in six major types.

Four are not specific to skiing: The *valgus-external rotation* (Fig. 27.10) where the skier makes an inside edge fault, which brings the involved leg outwards and causes the skier to fall forward. The medial collateral ligament of the knee (MCL) is the first affected, but it can be associated with a rupture of the ACL. Ruedl et al. (Int J Sports Med, 2011) have shown that the most frequent mechanism of injury found in ACL tears is the fall forward in Valgus-External Rotation or "forward twisting fall." It seems that it has become the most frequent lesion mechanism since the introduction of carving skis, regardless of gender; *knee hyperextension; the varus-flexion-internal rotation* (Fig. 27.10) which is often a trauma with low kinetic energy, even in snowplow, the external edge of the downhill ski is blocked, and the body weight by tilting downstream prints in a varus movement of the knee with internal rotation of the tibia which puts tension on the ACL; *complex distortions* that cause multiligament knee injury.

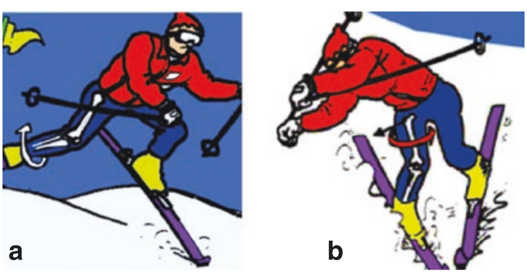

Fig. 27.10 Mechanisms and risk factors for ACL tears in alpine skiing: (**a**) valgus-external rotation and (**b**) varus-flexion-internal rotation

Two are specific to the practice of skiing: the "phantom foot" (Fig. 27.11) which corresponds to a forced internal rotation of the tibia under the femur with the knee bent more than 90° (downstream member), when the skier is unbalanced rear and only has the internal edge of its downstream ski in contact with the snow; "boot induced" (Fig. 27.11) which corresponds to a thrust of the tibia forward, when landing a jump, the tail of the ski first touches the snow while the knee is close to the extension.

Two other mechanisms have been described by *Chambat* in competitive skiers: hyperflexion combined with a strong contraction of the quadriceps at the start of a race can be at the origin of a bilateral rupture of the ACL; the "click-clack" which occurs during a stealthy episode of valgus-external rotation of the downstream knee which disengages from the upstream knee during a tight turn in competition.

The risk factors for ACL injury are gender first. Statistically significantly, epidemiological studies find more ACL injuries in women. According to the Association of Mountain Physicians, women's risk of ACL rupture is 3.5 times greater than men. Several studies show that this is not specific to skiing since, at sport and at the same level, reaching the ACL is more frequent in women (up to 4–6 times more frequent). The reasons are multifactorial: anthropometric (larger pelvis, tighter femoral arch, genu valgum), hormonal (more ACL lesions in the luteal phase, hormonal impregnation of the ACL), and neuromuscular (studies have shown differences in mechanoreceptors). Then, the lack of physical

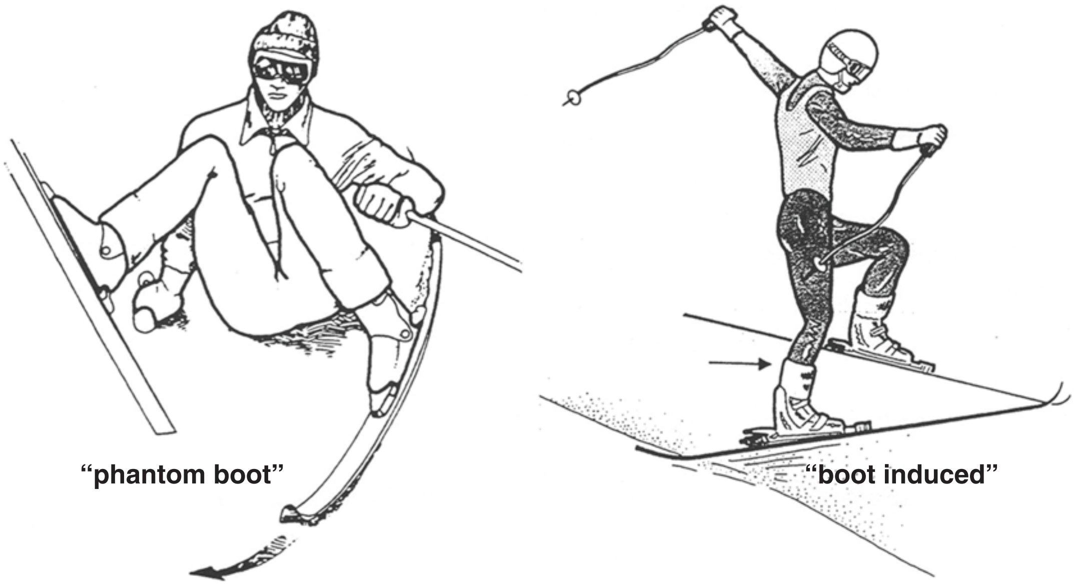

Fig. 27.11 Mechanisms of ACL injury in alpine skiing: "phantom foot" and "boot induced"

preparation: a lack of muscular preparation, especially at the quadricipital level, increases the risk of ACL lesions. Finally, unsuitable equipment: excessively long skis increase the stresses on the LCA, and improperly adjusted bindings (which do not trigger) are the cause of almost half of knee sprains. The binding adjustment criteria must consider the skier's gender, weight, height, and ski level.

27.16 Accidentology and Traumatic Pathologies Linked to the "Competitive" Practice of Snow Sports in a Group of High-Level Athletes

Since 2006, the International Ski Federation (FIS) has carried out retrospective monitoring of the trauma of professional athletes during the winter season 1–8. This work made it possible to better assess the incidence of different injuries during the season in the different disciplines.

Similarly, within the French Ski Federation (FFS), continuous prospective monitoring of ruptures of the anterior cruciate ligament (ACL) has been carried out since 1980 with French alpine ski teams. Since 2017, monitoring has expanded, on the one hand, to all disciplines (alpine skiing, freestyle skiing, snowboarding, and Nordic skiing), and on the other hand, to all traumatic and overuse pathologies.

27.17 Prospective Trauma Monitoring Within the French Ski Teams (Epitraumatic Cohort [1])

If the monitoring carried out by the FIS allows a global evaluation of the trauma of skiing, it is perfectible and incomplete since it is, on the one hand, a retrospective analysis and, on the other hand, an analysis relating to winter season only. Since 2017, the Medical Commission of the French Ski Federation has been carrying out a prospective follow-up on the trauma of all the athletes of French ski teams in all disciplines.

A first analysis was carried out between May 1, 2017, and April 30, 2018. Three hundred and twenty-four athletes who were divided into five disciplines: alpine skiing, freestyle skiing, snowboarding, jumping, and Nordic skiing were included in this study.

Two hundred and four injuries were recorded, an absolute incidence of 63 injuries per 100 athletes/season. In the literature, this incidence is much higher than those published in other studies which only took into account the winter season [2, 3]. One hundred and thirty-six athletes, or 42% of the population, presented at least one injury. One hundred and ninety injuries required a sports interruption, and 32.6% of them were considered severe, that is to say, they required a sports interruption of more than 28 days.

Traumatic injuries accounted for 77% of the cases. In alpine skiing, freestyle skiing, and snowboarding, these traumatic injuries represented most cases, while in Nordic skiing overuse injuries were the majority (Table 27.2).

Alpine skiing represented 37.7% of injuries, snowboarding 21.5%, freestyle skiing 20%, Nordic skiing 18.1%, and ski jumping 2.4%.

The analysis of the relative incidence reported on 1000 runs highlighted an over-risk of injury and severe injury (stopping>28 days) for snowboarding and freestyle skiing compared to alpine skiing (Table 27.3).

One hundred and four injuries (51%) involved the lower limb, including 43 knee injuries. The upper limb was affected in 19.6% of the cases. These findings are corroborated by the results of the literature [2–5]. The skull and cervical spine were affected in almost 20% of the cases for the freestyle (19.5%) and snowboard (22.7%) disciplines (Table 27.4). The Steenstrup [6] series also found a higher incidence of head injuries in the snowboard and freestyle disciplines compared to the alpine. It was concussions in over 80% of cases.

There was no difference in the distribution of injuries between summer and winter (46.8% vs 53.2% (ns)). On the other hand, there were significantly more traumatic injuries during the winter period (86% vs 65%) and more overuse injuries during the summer period (34.4% vs 14%) ($p = 0.001$). Almost a quarter of traumatic injuries occurred in January and February. The Pujol

Table 27.2 Number and percentage values of traumatic and overuse injuries according to the skiing sports modalities

	Alpine	Freestyle	Nordic	jumping	Snowboard	Total
Overuse (%)	21 (27.3)	2 (4.9)	19 (51.4)	0 (0)	5 (11.4)	47 (23)
Traumatic (%)	56 (72.7)	39 (95.1)	18 (48.6)	5 (100)	39 (88.6)	157 (77)
Total (%)	77 (100)	41 (100)	37 (100)	5 (100)	44 (100)	204 (100)

Table 27.3 Relative incidence of all injuries and severe injuries in every 1000 runs in each discipline: Alpine. Freestyle and Snowboard

	Runs (*n*)	All injuries (*n*)	Relative incidence	Relative risk	*p*-Value
Alpine	4642	72	15.5 [12.1–19.5]	1	Not significant
Freestyle	503	41	81.5 [58.5–110.6]	5.26 [3.58–7.71]	**<0.001**
Snowboard	616	43	69.8 [50.5–94]	4.5 [3.08–6.57]	**<0.001**
		Severe injuries (*n*)			
Alpine	4642	24	5.2 [3.3–7.7]	1	Not significant
Freestyle	503	11	21.9 [10.9–39.1]	4.23 [2.07–8.63]	**<0.001**
Snowboard	616	10	16.2 [7.8–29.9]	3.14 [1.5–6.57]	**0.002**

Table 27.4 The injury distribution according to the localization, and discipline of skiing

	Alpine	Freestyle	Nordic	Jumping	Snowboard	Total
Cranial and cervical spine (%)	3 (3.9)	9 (22)	2 (5.4)	0	11 (25)	25 (12.3)
Upper limb (%)	16 (20.8)	9 (22)	5 (13.5)	0	10 (22.7)	40 (19.6)
Trunk (%)	19 (24.7)	5 (12.2)	5 (13.5)	1 (20)	5 (11.4)	35 (17.2)
Lower limb (%)	39 (50.6)	18 (43.9)	25 (67.6)	4 (80)	18 (40.9)	104 (51)
Total (%)	77 (100)	41 (100)	37 (100)	5 (100)	44 (100)	204 (100)

study [7], with 25 years of experience, reported the same finding. Overuse injuries occurred mainly during the months of May and September.

27.18 Monitoring of ACL Ruptures Within the French Ski Teams

The development of the equipment played *a key role in the evolution* of the trauma of ski "competition." The turning point appeared in the late 1970s with the modification of shoes and the appearance of tall stems. While ankle and leg injuries have decreased significantly, knee sprains have increased. ACL ruptures now account for almost 35% of all trauma and 68% of knee trauma [2, 8].

The high incidence of ACL tears in skiers has prompted the FFS Medical Commission to set up a prospective collection of these lesions among French teams since 1980.

The results of this cohort analysis were published in 2007 and 2013, respectively [7, 9]. The study by Pujol and Chambat [7] assessed trauma in the World Cup and European Cup groups between 1980 and 2005. Three hundred and seventy-nine athletes (191 men and 188 women) were followed over this period. One hundred and five athletes presented at least one ACL rupture, i.e., 27.7% of the athletes followed. The gender distribution was homogeneous with 28.2% of the affected women and 27.2% of the men ($p = 0.21$). Women were affected significantly earlier (20 years vs 22 years ($p < 0.01$)). The prevalence of iterative ruptures was 19% and that of contralateral ruptures 30.5%. Regarding a first rupture operation, 39% of athletes were re-operated for a new ACL rupture (homo or contralateral).

The authors reported an incidence of 6.1 ACL tears per year. This figure remained broadly stable over the period analyzed, even though there was a downward trend in the female population while there was an upward trend among men. This incidence remained stable despite the evolution of ski equipment and techniques.

There were also three traumatic peaks during the season: first, in autumn for women, which corresponds to the end of the period of intense physical preparation and the resumption of skiing; second, at the start of the year, a busy period in races and a source of fatigue for athletes; and third, at the end of the season, which can be a sign of a certain relaxation and a lack of concentration.

Finally, the authors analyzed the incidence of ACL tears based on the level of the athletes. The rate of first ACL rupture was significantly higher in the group of athletes ranked in the 30 best skiers in the world ($p = 0.002$). Fifty percent of athletes ranked in the top 30 had at least one ACL rupture compared to 23% for the others. The rates of re-ruptures and contralateral ruptures were also significantly higher in the first group (38.5% vs 12.8% and 33.3% vs 11.4%). The authors noted that athletes ranked in the top 30 in the world had a longer career and that the occurrence of an ACL rupture had no influence on the length of their careers.

Similarly, Haida's study [9] analyzed the influence of the occurrence of an ACL rupture on the career of skiers in the French team. The study involved 477 skiers who joined the national alpine ski teams between 1984 and 2013. One hundred and forty-eight skiers had at least one ACL rupture during their careers. Athletes with an ACL rupture had a significantly longer career than those without an ACL rupture. According to the authors, the mental and physical capacities of very high-performance athletes as well as the optimization of the return to sport process by all medical and sports staff are the keys. In addition, all the athletes who had a rupture of the ACL continued their careers after the rupture.

Age is described in the literature as being closely correlated with performance level [10, 11]. Skiers who improved their performance were significantly younger (men: 22.2 ± 3 years; women: 18.7 ± 2.2 years) than those who did not improve (men: 25.3 ± 4.2 years; women: 22 ± 4 years). The authors emphasized that the time to return to the best level was 3.8 ± 3.1 years for men and 3.1 ± 2.5 years for women, and that the peak performance was reached on average at 25.1 years for men and 25.3 years for women.

Conclusion

The trauma of skiing and snowboarding is constantly evolving due to the modifications made to the equipment, from the boot to the ski or to the board, via the bindings.

The development of the equipment played a key role in the evolution of the trauma of "leisure" or "competition" skiing. The turning point appeared at the end of the 1970s with the modification of shoes and the appearance of tall uppers which limit trauma to the ankle and leg, but which considerably increased severe knee sprains. The evolution of the board and the arrival of carved ski, when it increased the speed and the inclination of the skier, are responsible for an increase in upper limb injuries, and the severity of the trauma that often occurs at speeds is more important.

Trauma is also influenced by external factors such as the preparation and congestion of the slopes, snow conditions, and weather conditions.

Education, good citizenship, and self-discipline should make it possible to reduce the accidentology of snow sports, which has already decreased considerably over the years since 1960.

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