Chapter

Ski Lesions Around the Knee: A Literature Review

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Abstract

Ski is a popular sports practiced worldwide although it is considered a high-risk sports with high incidence of injuries. A common place for injuries is the knee, with a wide range from knee sprains to complex ligamentous injuries to fractures. In this chapter, we made a search in PubMed using the words "knee" and "ski." Later, we selected those articles according to the inclusion criteria. When reviewing the literature, we found that the most common place for a ski-related injury is the knee, with knee sprains and ACL lesions being the most common diagnosis in the latter years with a decreasing incidence of tibia fractures. We could also analyze the risk factors different authors have found, for professional athletes and for recreational skiers. In conclusion, the ACL lesion in the skier presents a high incidence, which suggests an effort should be made to prevent it.

Keywords: knee, ski, ACL, ligament, MCL

1. Introduction

Alpine skiing is a very popular sports with an increasing number of participants worldwide although being considered a high-risk sports with a high incidence of injuries in its participants. It is a sports with a great diversity in the profile and level of people practicing it, from amateur skiers to professional athletes with a high number of hours of exposure to injury risk.

Among the most frequent injuries, there are those affecting the knee joint, with a wide specter of severity: from mild sprains or contusions to serious multiligamentary injuries or complex fractures.

The aim of this study is to perform a literature review to assess the more common injuries in alpine skiing, see if there is a change in recent years due to new equipment and attitudes, look for its risk factors, and analyze possible preventive measures to reduce the risk of serious injuries.

2. Epidemiology

Alpine skiing is the most popular winter sports [1] worldwide. Only in the United States, more than 18 million people 5 years old or older participated in alpine skiing or snowboarding at least in one occasion in the 2011–2012 season [2], and there are about 200 million skiers worldwide [3]. Even more this popularity seems to be increasing all around the world.

Professional skiing is also a popular sports, with 3625 ski races arranged by the International Ski Federation (FIS) in the 2007–2008 season, of those 74 were Alpine Ski World Cup races in which up to 443 athletes participated [4]. Ski racing comprises diverse disciplines from aggressive-turning and highly technical demands like slalom to high speed with big jumps with almost no protective wear like downhill. Besides, alpine ski racing is a popular TV sports, with up to 250 million of TV spectators in 2009 according to FIS data.

It is a well-known fact that skiing is a sports with a high incidence of injuries, some estimate about 2.5–3 injuries per 1000 skier days in amateur practice [3], with head trauma and injuries around the knee being the most frequently reported. Knowing this data one can simply imagine the huge sanitary, social, and economic burden that skier injuries suppose in our societies.

3. Material and methods

A literature search was made using the PubMed database. We used keywords as ski and knee in order to maximize the number of results. In this first search, we obtained 285 results. We decided to include articles from 1995 to 2018 to be able to compare data published before many technological innovations were introduced with more recent data; this limited the number of articles to 211. All titles and abstracts were analyzed to identify the articles of interest: those investigating about the incidence, types, and risk factors for knee injuries during the practice of alpine skiing in adult population, either amateur or professional.

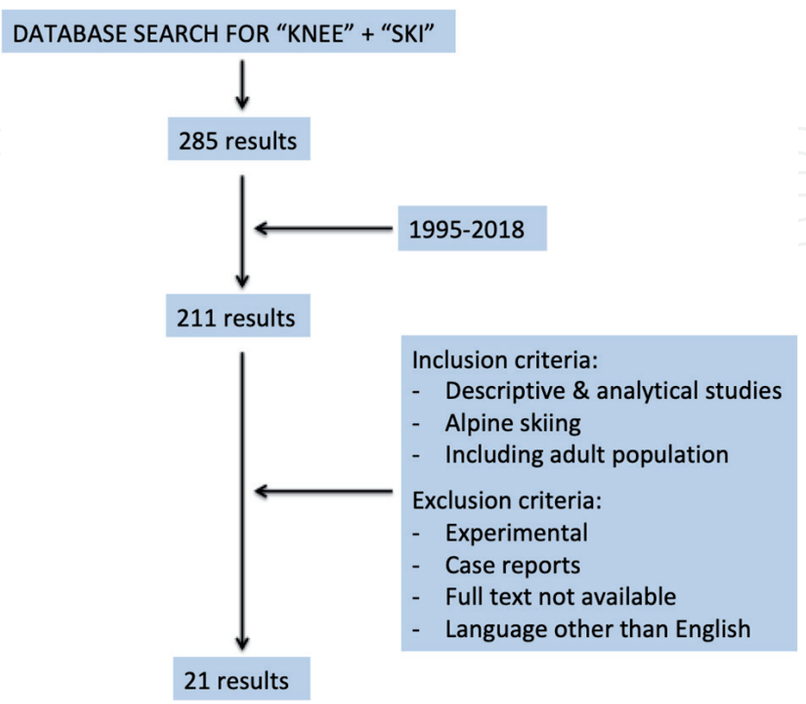

Figure 1.
Chart showing the selection process of our study.

Descriptive and analytical studies were included, and some reviews were taken into account for its particular interest and value. Experimental and laboratory studies were excluded, as well as case reports. We had to discard all articles not written in English and those whose complete text was not possible to obtain for any reason. All the process with its phases is detailed in **Figure 1**.

Given the reduced number of studies with high-quality evidence in knee injuries in alpine skiing, it was deemed that the best methodology was to do a narrative review.

4. Results

After applying the process explained in the previous point, we had 21 results, 18 original articles, and 3 reviews.

When analyzing all the studies, the first thing that stands out is the big variability between them. We could find studies referring to professional athletes and others to general amateur skiers. We could also find studies done in high-level trauma centers and others done in small ski resort clinics without a physician, with great differences in the diagnostics and clinical information reported. Moreover, the studies' designs also presented a great variability.

4.1 Athlete skiers

Referring to the alpine ski racers' population, Stenroos and Handolin [1] reported no differences in the absolute injury rate in men compared to women, although the mean age of their study is 14 years old, which in our opinion can produce some bias. The most common injury mechanism was the fall down on the same level, with 56% of injuries taking place on giant slalom runs (characterized by higher speed runs) and 31% on slalom runs. About 74% of injuries in this study group required hospitalization. Knee injuries represented the 34.4% of all injuries: 81% were ligamentous injuries being 47% of them anterior cruciate ligament (ACL) injuries (which means the ACL injuries were the 13% of the total). Ligamentous knee injuries were more common in women than in men; in the ACL group, 75% of injured skiers were women. Recovery after an ACL injury took a mean time of 175 days (range 150–180 days) without skiing, and all those patients reported mild or great discomfort in skiing 6 months after the injury. No knee fractures were reported; but 26% of injuries were leg (tibia and fibula) fractures, a surprising high rate when comparing to literature, probably due to the relative young age of this study population.

Similar results were reported by Schmitt et al. [5] in a study in athletes in the Swiss national ski teams. A knee injury rate of 35% was reported, with no differences between men and women; 71% were ACL injuries, of which 26% were isolated ACL injuries and 44% presented an associated injury of a collateral ligament and/or menisci. Their conclusion is that ACL is the most frequent knee injury in competitive alpine skiing. In their objective to describe risk factors for ACL injury, they report a higher risk in slalom runs (with more aggressive and technical turns but at lower speeds) and in athletes with better FIS score and rank, highlighting a higher prevalence of ACL ruptures in the top 30 World Cup skiers. Finally, body mass index, weight, and fitness status (assessed with a specific fitness test: Swiss Ski Power Test) did not correlate with ACL injury risk.

In two successive studies, Flørenes et al. [4] and Bere et al. [6] investigated the sex differences in risk injury in World Cup skiers, first for two seasons [4] and then for six seasons [6]. They report a mean absolute injury rate of 36.2 injuries/100 athletes/season with a higher relative injury rate in men (11.3 injuries/1000 runs)

than in women (7.1 injuries/1000 runs). Of this 82.3% were time-loss injuries, with 43% being reported as severe (absence from skiing >28 days) and 31% moderate (absence 8–28 days). 45.5% of the injuries took place during the World Cup races. Knee injuries represented the 38% and lower leg and Achilles tendon injuries the 9%. In ACL injuries, there were no sex differences (5.4 ACL injuries/100 athletes/season in men vs. 5.5 in women).

When analyzing knee injuries, they reported that 83% were ligamentous injuries, of which 45% were ACL injuries (that makes the ACL the most common ligament injury), and only 4.4% were fractures. They report that 50% of knee injuries are classified as severe. The relative ACL injury rate was higher in downhill and supergiant races (high speed with softer turns) than in giant and slalom races; this result matches with Stenroos' study results [1].

In [7, 8], Jordan et al. made a review in which they report literature finding that only 55% of alpine skiing athletes are able to return to their preinjury level after an ACL rupture. They also support the result we have found that in this group of skiers there is no sex difference in ACL injury rates.

4.2 Amateur skiers

Referring to amateur skiers, Patrick et al. [2] made a study comparing injury epidemiology in skiers between the 1996 and 2013 seasons. In both years, the knee was the most commonly injured body part (28%). An interesting fact they report is that helmet use augmented from only 6 to 84%, which means that although there is an increasing effort to make skiing a safer sports this has had no impact on the amount of knee injuries. They also report and increase in injuries among people older than 45 years. This results match with the published by Stenroos et al. [1] when they report an injury risk of 1 injury/10,000 ski lifts or in their calculation 1.97 injuries/1000 skier days in amateur people. Knee lesions were the 28.5% of the total, almost half of them being suspected as moderate or severe injuries. A major limitation in this study, which is also present in similar ones, is the lack of precise diagnostics, as data is collected by rescuers and/or in small ski resort clinics.

Continuing with the epidemiology review, Girardi et al. [9] studied factors affecting injury severity using the Injury Severity Score (ISS). They found that being a man and being older than 60 years were risk factors for an increased ISS, while the ISS was lower in beginner skiers and during a snowfall. There is no information in this article about these risk factors relating to knee injury risk. In [10], Khalilifar et al. report a lower knee injury rate, of only 14%, but this rate being higher in women, a result also found in other studies [11–14].

In [15], Davidson and Laliotis, a 9-year survey (from 1983 to 1992) of injury patterns in alpine skiers, reported an increase in injury rate from 1.9 to 3 injuries/1000 skier days. Knee injuries were 35%, and what is more relevant is a 92% increase in the number of knee injuries during their study period.

A very similar study period is researched by Warme et al. in [16] reporting a stable injury rate of 3.7 injuries/1000 skier days and knee injuries being 34% of the total. The most relevant part is that they report an exact diagnostic information (30% of the total on injuries affected the knee ligaments): 18% the medial collateral ligament (MCL), 16.5% the ACL, and in 20% of knee sprains, both ligaments were affected. They report a significant increase in ACL injuries.

Coury et al. [17] compared the epidemiology of skiing injuries in a ski resort clinic between 1995 and 2000 and the 2009/2010 seasons. Their results show also the knee injury as the most frequent (43%). Knee ligament sprain or strain was diagnosed in 25% on injured people, 10% with torn cruciate ligament, and 6% with what they call "internal derangement of the knee" (probably, a torn meniscus was

to be diagnosed in this group of patients). Skiing injuries were more common in intermediate- or advanced-level skiers, but beginner skiers were the ones most at risk for knee injuries. They report only 3.2% on tibia and fibula fractures, and only 3.6% of ankle injuries in skiers, while snowboarders present up to 13% of ankle injuries. This difference may be explained by the use of hard-shell boots in ski.

A recent interesting study [18] discusses about injuries from 2001 to 2006 in a level 1 trauma center, which probably means a loss of minor injuries but on the other hand can inform about the most severe ones. They report a 52.3% of lower extremity injuries, the majority classified as soft tissue knee injuries but with a 2% of knee dislocation, 26% of tibia fractures (ankle not included), and 15.7% of femur fractures. The mean hospitalization rate was of 3.36 days, and 13.9% of patients required a surgical intervention. In our opinion, the high rates of severe injuries, especially major bone fractures, are because of a selection bias due to the nature of the hospital where the study took place. Results published by Ekeland et al. [19] support our conclusion: injury rate of 1.27 injuries/1000 skier days with leg fractures being only 3.6% in adult population. In children these fractures made up to 12.6% of injuries. They conclude that while there was a huge reduction in leg fractures during the 1970s–1980s probably due to higher quality of boots, making them higher and hard-shelled, and bindings, this reduction was not observed in children to the same degree.

In the same direction point, the article by Castellani et al. [14] reported that fractures in skiers are more common in men and especially in younger patients (<15 years old). Knee injuries are the most common (28.3–31.3% of injuries), with knee fractures being between 2 and 5%. A result that is important to be highlighted is their finding of an increased risk in women for knee ligamentous injury: men presented 14–15% of ligamentous knee injuries and 36–41% in women. In their data, the hospitalization rate was of 26%, from which 62% underwent surgery; mean hospital stay was 10.5–12.8 days. Knee arthroscopy was realized in 1.9–6.3% of operations. These results can be biased by the fact that almost half of injured patients were referred to their home hospital for treatment of lesions; and as ligamentous injuries are not a surgical emergency, the probability of being referred to in the presence of such an injury grows when compared to a patient with a fracture.

4.2.1 Risk factors in amateur skiers

Some studies did an effort to clarify which risk factors play a role in knee injuries in alpine skiers. As commented before this is a more heterogeneous group with big differences with respect to ski racers, so risk factors may be completely different.

Sulheim et al. [20] reported that beginners (OR 2.7) and children younger than 13 years old (OR 1.32) were more at risk for injury. In their data, 27.3% of injuries affected the knee joint, and more than half of injuries required reference to a hospital as a potentially severe injury was suspected. When considering knee injuries alone, they also found that beginners (OR 3.13) were at increased risk, which matches results found by Coury et al. [17]. Alpine skiing was a risk factor for knee injury (OR 1.82) when comparing with other snow sports like snowboarding and telemark.

Ruedl et al. [13] confirm that women are at higher risk for knee and ACL injuries presenting almost double prevalence for this kind of lesions in their data (30.1% in men and 57.4% in women). They report that 93% of knee injuries happened on slopes, and while off-piste skiing had a higher risk injury, it was not at an expense of knee ones. When analyzing by sex, no environmental risk factors for knee injury were found in men, while in women skiing during a snowfall doubled the prevalence on knee injuries compared with injuries of other body parts. Additionally, they found an increased risk when temperature was low (OR 1.6 when skiing at −10°C vs. +2.7°C). Finally, in this study more knee injuries were found in situations

of grippy snow in which, as reported by them, this finding is contrary to other literature reporting a higher index on icy snow.

A very interesting study [11] researched the relationship between ACL injury and ski binding failure. In this study 77.9% of ACL-injured patients reported a failure of ski bindings to release. The percentage of failure to release bindings was even higher in female skiers, in skiers injured after a fall backward (vs. a forward fall), and in those who were skiing slow or very slow. There is always a significantly higher percentage of failure to release in patients diagnosed with a complete tear of the anterior cruciate ligament (vs. those with a partial tear), probably because when the ski is not released it acts as a lever at the knee joint for a longer time. Similar results are reported in [12]: bindings only released in 23.8% of knee-injured skiers, with an even worse percentage if only adults (>18 years old) are considered, and 19.3% of binding release among amateur skiers with a knee injury.

5. Discussion

In the elite alpine skiers, there is a high injury rate, especially in knee injuries and ACL. This high prevalence of knee ligament injuries can also be found in amateur skiers, but probably a more aggressive skiing and risk-taking behavior trying to achieve the best results is what explains the higher injury rate in this expert skiers' group. Comparing to studies done in general population, studies in ski racers present better data with more exact diagnostic information and prognosis. ACL and other knee structure injuries present the same incidence in both men and women; this was a surprising finding when taking into account what literature reports about amateur skiers and other high-risk sports for ACL injury: a higher incidence in women. Differences in skiing technique, fitness, behavior, and equipment between elite alpine skiers and amateurs may explain why ACL injury rate is equal in men and women, among ski racers. Whatever the reason is, in our opinion an effort should be made to minimize ACL injury risk in all athlete skiers, as it is a devastating injury that can be the end of the skier's professional career. We found no agreement in the literature about the most dangerous alpine ski discipline for the knee: slalom is characterized for aggressive technique with short turning-radius skis, which may be a risk factor of a knee ligament lesion with a rotational injury mechanism; on the other side, downhill and giant slalom are characterized for higher speeds, which means higher kinetic energy, plus the fact that a longer ski means a greater lever-arm rotational force being transmitted to the knee joint.

Even with the limitations present in studies involving amateur skiers due to their heterogeneity in methodology and limits on precise diagnostic, treatment, and follow-up, we found that the knee joint is the most frequently injured body part, and some studies show there is an increasing trend in ligamentous knee injuries among alpine skiers. Literature found reports that up to half of the injuries are moderate or severe, especially among older skiers, who present a higher injury risk and also a higher risk for serious injury. In our opinion this may be explained by the decrease in physical capabilities associated with aging. Another group at risk for knee injury is the beginner skiers; no explanations for this were found in the literature. In our opinion a poorer technique, bad decision taken related to poorer risk awareness, and probably less knowledge about the correct settings of equipment gear as ski bindings may explain it.

As also found in other sports studies, amateur women have a higher ACL injury risk when skiing. This was found to be supported widely in literature [10–14]. To explain this difference in incidence, we found literature suggesting on a combination of intrinsic factors: anthropometric differences, decreased notch width,

augmented articular laxity and muscle (hamstring) flexibility, age, fitness status, and menstruation phases, plus the extrinsic ones such as the type of ski, ski binding setting, slope, and weather. We agree that most probably a combination of anatomic, functional, and extrinsic factors justifies this higher risk. The exact reasons have still to be discovered, but at least we should be able to focus the preventing efforts in the higher injury-risk groups.

We found literature reporting that in 44% of lower extremity injuries (in 44% of MCL injuries and 43% of ACL injuries) skiers were going slow or were stationary, meaning that skiing slowly increments the risk for ACL injury and the risk of bindings fails to release. This last result probably explains the increased ACL injury risk in a fall when skiing slowly, as a lower kinetic energy, should mean a lower injury risk for knee structures.

Skiing in bad weather situations, lower temperature, and/or during a snowfall also were risk factors for knee injury, especially in women. The explanation for this last finding may be the increased risk of cooling which causes a decrease of muscle performance. In [13], there is reference to literature where a 10 times increase in ACL injury risk is reported in bad light conditions and also in case of strong snowfalls (double of risk) probably due to bad visibility plus lower temperatures. In our opinion bad visibility conditions like snowfalls are high-risk situations as it can make the skier to run into bumps able to turn the ski without being able to see and avoid it. This knowledge should be used to warn or even prevent people from skiing in bad weather days.

5.1 ACL biomechanics and injury mechanisms

As multiple articles in the literature report, the ACL is probably the most common injured ligament of the knee in alpine skiers. The second most common injured structure would be the MCL, although not all series agree on this order.

The anterior cruciate ligament is a primary stabilizer of the knee joint, being the main structure to resist tibia anterior translation with respect to the femur. It also restricts tibia internal rotation with knee between 0 and 30° of flexion, prevents hyperextension, and is a secondary stabilizer against the valgus, especially with the knee in extension, when the MCL has a decreasing role.

The medial collateral ligament is the most important knee-stabilizing structure in the medial part of the joint; its main function is to resist the valgus forces and tibia internal rotation and has a secondary role in preventing the anterior translation of the tibia with respect to the femur.

As just seen both ligaments have similar or supplementary functions and are believed to act synergistically. This can explain the prevalence of combined total and partial injuries in skiing and other sports accidents. In other ACL injury high-risk sports, such as soccer, this lesion usually happens when with a foot planted on the ground the player does a sudden deceleration plus external rotation and/or valgus, presenting a twist at the level of the knee joint. Skiing mechanics involve a dual-surface movement [17], and skiers tend to sustain injuries when the ski catches an edge and there is a body torqueing with relation to the knee joint.

A consequence of special mechanics involved in skiing is that several injury mechanisms have been proposed. Shea et al. [12] affirm that injury mechanism in elite and amateur skiers might be different, a point partially supported by other literature when they report different percentages of each injury mechanism in each one of these groups.

In [12], and also in two interesting reviews [7, 21], proposed injury mechanisms are explained; a summary of this is of high interest for a better understanding of knee injuries in skiers:

- Valgus external rotation: after losing balance and shifting the center of gravity forward, the inside edge of the ski touches the ground producing abduction and external rotation of the tibia, while the skier's body advances respect to the knee, creating a valgus force. This mechanism is thought to damage the MCL and the ACL due to the valgus plus the rotation force applied to the knee. The presence of a valgus deformity may also cause a lateral meniscus traumatic tear. This was found to be the most common mechanism of injury in recreational skiers (up to 32.9% of cases) since the generalized use of carving skies [11, 12], and in one publication [12], it was related to high-level amateur skiers. This injury mechanism was found to be related with the failure of ski bindings to release [11].

- Hyperextension internal rotation: occurring in heavy snow, it happens when the ski is slowed while the body keeps advancing forward. Usually, it associates a crossing of ski tips, producing internal rotation and varus force. The forced internal rotation in a probably extended knee is responsible for the ACL injury; as in an extended position, the ACL is the main knee joint restrictor against the internal rotation. This forced movement can also damage lateral structures like the lateral collateral ligament by distraction or the lateral meniscus if it is trapped under the femoral condyle when turning. This is the reported mechanism in 19% of injured skiers.

- Boot-induced anterior drawer: when the skier lands from a jump, the ski tail is the first part to contact the snow causing the body weight to go backward while the leg is driven forward by the boot attached to the ski, applying an anterior force on the tibia. This effect can be increased by a strong quadriceps contraction to avoid a fall. With this mechanism the ACL is putted under great tension to avoid the anterior translation of the tibia with respect to the femur causing the injury. As the ACL is isolated and there is no rotation or varus-valgus deforming forces, the MCL and other knee structures remain unharmed. This mechanism was reported as the one responsible for only 7.8% of ACL injuries in amateur skiers [12], but it seems to be the most frequent mechanism in elite skiers [4]. Ski bindings are not designed to release when a backward-directed force is applied in the absence of rotational forces, so in this mechanism bindings will not release.

- Phantom foot: it happens when the skier losses balance and falls backward on the rear part of skis, placing the hips below the knees with all body weight on the downhill ski, which internally rotates the knee in hyperflexion. Knee hyperflexion puts the ACL under strain, which facilitates its injury due to the forced rotation. The MCL is also injured, as it is the main restrictor structure against internal rotation in the flexed knee. The fact that all body weight is on this ski makes the lateral meniscus vulnerable to injury as it can get trapped under the turning femoral condyle with axial load. This was reported as the most frequent mechanism before the introduction of carving skis [11], and a recent study reports a 22.5% of cases caused by this mechanism, being the second most frequent in skiers between 30 and 40 years old [12]. There is no agreement in literature about the influence of ski binding's failure to release in these cases.

In elite skiers another two mechanisms have been described:

- Dynamic snowplow: with the weight backward and skis in split position, the unweighted ski forces the knee in valgus and internal rotation. It is believed to be the cause of 15% of ACL injury. It has big similarities with the hyperextension mechanism. The ACL, and also the MCL, limits knee valgus and internal

rotation, so in this mechanism both structures are under strain and vulnerable to injury.

- Slip and catch: it is very similar to the previous one but is considered more frequent. This happens during a turn, after losing contact with the snow by the outer ski; when it recovers the ski catches the edge causing rapid flexion, internal rotation, and valgus. A very important reported fact is that in 100% of slip-catch ACL injuries in athletes ski bindings do not release or are release after the injury took place [7].

These two mechanisms are believed to be related with the use of more aggressive and smaller turn radius skis like the ones used in slalom races; even some authors suggest that carving skies (shorter, wider in tip and tail, easier to turn) may augment the injury risk as their design may increase kinetic energy in slopes [7], although this last point is controversial [12].

5.2 Associated injuries

When an ACL injury occurs, other knee joint structures may be at risk, as up to 68% of skiers with an ACL injury present a lesion of another knee joint structure.

If, as seen before, a valgus force is present in the injury mechanism, the medial collateral ligament will probably suffer a tear; the rate of associated ACL + MCL injury has been reported between 16 and 57% [21]. The isolated MCL injury is caused by a direct valgus load of the knee. A problem exist in preventing these injuries, as ski bindings are designed to release when falling forward or when rotating force is applied, so no releasing mechanism exists in cases of isolated valgus torque.

In alpine skiing, the most commonly affected menisci is the lateral. This is reported to be found in 23–55% of ACL-injured knees. Some authors [2, 21] tried to explain the lower incidence of menisci lesions in ACL-injured knees when comparing to other ACL injury high-risk sports. The fact that some injury mechanisms are caused by forces that do not contain rotation or valgus may explain that. Another point is that, contrary to soccer or basketball, at the moment of injury in skiing there can be a distraction of the knee joint and by that not loading the meniscus and saving it from tears and less secondary trauma to the joint. Independent of the cause of a lower incidence of menisci, cartilage, and other joint structure injuries, this is a positive point, as all these lesions can be responsible for the onset of early osteoarthritis in young and active patients.

In two literature reviews, we found contradictory affirmations about the trends in tibia plateau fractures, associated or not with ACL injury. In [3], authors report the finding of a rise in tibia plateau fractures, almost in all cases affecting the anterior part of the lateral plateau (Schatzker I, II, and III fractures) caused by valgus axial forces. In an opposite direction point, the results found in [21] report a 92% decrease in tibia plateau fractures from 1970 to 2003. In our literature review, reports about fractures affecting the knee joint are very scarce, and even some articles are done in ski resort clinics without RX; others are done in hospitals with all diagnostic methods available. In our opinion, it is very improbable that a tibia plateau fracture can go undiagnosed as the injured skier would not be able to go to his home hospital, a situation much more probable to happen in cases of minor injuries or even moderate to severe knee sprains.

A conclusion present in the vast majority of literature reviewed is the low prevalence in ankle and lower leg injuries in adult skiers, either amateur or elite athletes. Ankle and tibia diaphysis fractures were once the most feared and frequent injuries; but there are [3] reports of a 92% decrease in ankle fractures and sprains and up to 80% decrease in tibia fractures since the 1970s.

A general agreement is found in the literature and is also of our opinion that the reason for such a decrease in lower leg injuries while knee injury rates have grown or at least maintained is the change in the skier's equipment. Back in the 1960–1970s, ski boots were made of leather, shorter, and soft-shelled. It is evident that a major change has occurred; nowadays, boots are made of plastic, hard-shelled, and much higher than before. Ski is still a high-risk sports, with falls with or without collision being very frequent; and the kinetic energy of the fall is the same than it was 30–40 years ago. With actual equipment these forces bypass the ankle joint and the leg with all the energy absorbed and dissipated at the knee joint's level. In the authors' opinion, the sole fact of the existence of an injury mechanism called "boot-induced anterior drawer" should be enough to prove this point.

Another gear part that has had major improvements in quality is ski bindings. It is very probable that these changes also played a role in the decrease of lower leg fractures and are considered as key safety equipment. Ski bindings are designed to release when there is a fall forward with or without body rotation (reproducing the most frequent injury mechanisms) but are not done to free the skier's foot in case of a backward fall. In our opinion this is a big design deficiency that has to be fixed soon if there is a will to make skiing a safer sports. The problem now is that, as explained previously, several articles report high percentages of ski binding failure to release, especially linked to some injury mechanisms. In our opinion these equipment failures' high rates are to be considered unacceptable, and efforts have to be made to keep improving with the goal of reducing skiing injuries, particularly those affecting the knee joint.

5.3 Treatment

When considering the management and treatment of knee skiing injuries, the first thing that surprised us is that the majority of authors made no reference to it. Publications using small ski resort clinics, some of them without physician and/or diagnostic tools, admit its limitations and explain their procedure for referring patients with a suspected severe injury to hospitals. In other cases, with data obtained from these near hospitals, great treatment and follow-up evolution are lost when referring the patient for definitive treatment to his/her home hospital [14]. A limitation present in both study types is that of skiers with minor or moderate injuries that do not seek medical attention or that do it later in their home hospital.

Only in [1] et al. report the time loss after an ACL injury in elite skiers, but many times this is a population group with big differences in treatment strategies and goals.

Nowadays, the gold standard treatment for an ACL complete tear in a relatively young and active patient is its reconstruction. Debate about the better technique (mono- vs. bifascicular reconstruction, type of graft, graft fixation, etc.) is a topic outside this review's objectives.

It is also generally accepted that the treatment for an isolated MCL injury is a conservative treatment, which is thought to heal without sequels. There is less evidence about the best treatment of ACL and MCL combined injury.

Some surgeons affirm that the best method is to treat each injury in its gold standard way: surgical reconstruction of the ACL and conservative treatment for the MCL. Others argue that in a combined injury an anterior and valgus instability is present and that for this reason the MCL will not heal properly in the presence of an injured ACL. To solve this problem, there are two options, an operative reconstruction of all injured structures and an early surgery for ACL treatment, which would allow for a successful MCL non-operative treatment.

In our opinion, the majority of combined injuries should be treated with surgery but only for ACL reconstruction. We do not agree with the idea that an early ACL

reconstruction surgery is needed; in fact, for us a delayed ACL surgery is a better option, waiting until medial stability is recovered. Only in cases with a grade III MCL tear with great knee instability after at least 2 months of MCL tear conservative treatment, we recommend its surgical treatment, with plasty reconstruction of both structures.

6. Conclusion

Alpine skiing is a high-risk sports with an elevated number of people injured every year. Ligamentous knee injuries are among the most common, and it does not seems to be any tendency to decrease its high rate despite changes in attitudes and equipment that have lowered the number of other serious injuries. As seen, the percentage of knee injuries that can be considered severe is high, with ACL tears as the most common knee injury. Having such high rates of serious injuries in alpine skier's knee implies big challenges in prevention, to identify skiers at risk and to improve equipment parts that are proven to be failing. More research needs to be done to define all risk factors so that prevention efforts can be well directed. Also, more research is needed to identify the best treatment option for ACL and other knee ligamentous injuries, and consensus in treatment and rehabilitation protocols are needed for both elite athletes and amateur-injured alpine skiers.

Conflict of interest

Authors declare no conflict of interest.

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