[Primary Care]

Myths Concerning Alpine Skiing Injuries

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There are many commonly discussed myths about ski safety that are propagated by industry, physicians, and skiers. Through a review of the literature concerning 12 such topics, this article demonstrates that the following are untrue: (1) Broken legs have been traded for blown-out knees. (2) If you know your DIN (a slang term for *release indicator value*), you can adjust your own bindings. (3) Toe and heel piece settings must be the same to function properly. (4) Formal ski instruction will make you safer. (5) Very short skis do not need release bindings. (6) Spending a lot of money on children's equipment is not worth the cost. (7) Children need plenty of room in ski boots for their growing feet. (8) If you think you are going to fall, just relax. (9) Exercise can prevent skiing injuries. (10) Lower release settings can reduce the risk of anterior cruciate ligament injury. (11) Buying new ski equipment is safer than renting. (12) Skiing is among the most dangerous of activities. It is important for the skiing public, physicians, and all those interested in improving skiing safety to verify the measures they advocate. The statements analyzed here are simply untrue and have the potential to cause harm if taken as fact by those exposed to these unsupported opinions.

Keywords: skiing injuries; injury trends; injury prevention; unproven opinions; ski bindings

The 12 statements researched in this review have been presented in the lay and scientific literature as confirmed facts. They are examples of myths in the classic sense: a belief whose truth or reality is accepted uncritically. In several of our examples, common sense or personal opinion would lead some to believe that there is truth to the statement being considered—that is, level 5 evidence of the truth.[42] When the available research is scrutinized, all or at least part of these myths cannot be substantiated.

The incidence of alpine skiing injuries and the related factors are based on carefully devised level 3 studies using case-control methodology. According to Wade, such "findings would be difficult to obtain, if not unattainable, through any other experimental method than the case-control study design."[65] Although case-control studies cannot prove cause and effect, they can demonstrate associations that make it possible to draw conclusions and make recommendations concerning equipment design, function, and testing with standard practices that have made skiing much safer during the past 35 to 40 years.[65] Level 1 or 2 studies were not found on the 12 topics analyzed.

MYTH 1

Skiing is among the most dangerous of activities

As with so many things in life, it just depends. If we consider deaths, activities such as driving an automobile and using a bicycle involve a risk of death on a per hour of exposure that is similar to skiing. However, the risk of tearing an anterior cruciate ligament (ACL), is much higher while skiing.

To make meaningful risk comparisons between activities and exposure, risk must be normalized on the basis of exposure time. In the following analysis, time in an automobile is compared to biking and skiing.

The widespread use of automobiles and bicycles suggests that the associated risk is generally acceptable. The approximate annual death toll associated with cars (40 000) and bicycles (1000) is far greater than that for skiing (30).[1,45,54] The risk of traumatic death while skiing has not changed over the past 30 years[54]: 0.71 deaths per million event days of exposure. If we assume that each skiing day is 6 hours, this results in an estimate of 0.12 deaths per million hours of exposure. In 1969, Chancey Starr[60] estimated the risk of death on US highways at roughly 1 death per million hours of exposure. The US automobile fatality rate in 1970 was 4.7 per million miles,[38] and the 2007 rate was 1.42,[45] a decline by a factor of 3.3. In 1991, the US Consumer Product Safety Commission estimated[7] that 66.9 million bicycle riders rode an estimated 15 billion hours and sustained an estimated 1000 deaths: a fatality rate of 0.07 deaths per million hours of exposure.

Consequently, skiing does not look especially dangerous relative to other common human activities. The risk of death expressed as the number of fatalities per million hours of

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exposure seems to be on the same order of magnitude as death by car or bicycle—in the range of about 0.1 deaths per million hours of exposure.

Unfortunately, if the risk of interest is a grade III ACL injury, then the risk in skiing is high.[17,49] The risk of an ACL injury resulting from skiing accidents in 1995 ranged from 30 to 70 injuries per 100 000 skiers per day, which is comparable to football at 60 per 100 000 players per day. The general population risk of ACL disruption is 30 to 40 such injuries per 100 000 people per year (not day), making the risk for skiing in the general population about 365 times higher.[17]

In the case of ACL injuries, the relative risk of skiing injury versus bicycling, hiking, boating, football, soccer, basketball, or hockey cannot be determined. There are no comparable epidemiological or case-control studies of common recreational activities that would allow for a meaningful comparison, owing to differences in research methodology, injury definition, populations at risk, and exposure to risk. It is therefore a myth that skiing is the most dangerous of activities. In terms of deaths per million hours of exposure, it is no more dangerous than riding in a car or on a bicycle. The most common injury in skiing is an ACL disruption.[29] This risk is high compared to that of the general population, and it is about equal to that of playing American football.[17] Note that the overall rate of injury in skiing has dropped 55% over the 34 years ending in 2006 and that ACL sprains have dropped by 42% over the 14 years ending in 2006.[29]

MYTH 2

Broken legs have been traded for blown-out knees—a bad bargain

Snow sport injuries have been studied at a northern Vermont ski area in an ongoing case-control study for 37 years beginning in the winter of 1972-1973. From the early 1970s through the late 1980s, an 83% decrease in the incidence of sprains and fractures below the knee has been observed.[17,28] Since the 1980s, there has been no change in the risk of a lower leg injury, although a subgroup of twist-related injuries (spiral tibial fractures and ankle fractures and sprains) has shown a modest improvement beginning in the late 1990s. ACL sprains began to increase in incidence in the late 1970s.[28,29] By the early 1990s, the risk of sustaining a severe knee sprain had increased by 240%.[29] Since then, there has been a modest improvement, although ACL sprains remain the most common injury in skiing.[28,29] Trends in incidence for these 2 injury groups are not related. They are, in fact, out of phase with each other by 5 years or more, negating the cause-and-effect argument and making it unlikely that as one injury improves the other injury worsens.

Ski bindings were designed to protect the tibia, not the knee. All available evidence links lower leg injuries to the function and calibration of the release system.[16] The function and calibration of equipment from skiers with ACL sprains is virtually identical to that of an uninjured control group. The trends in these 2 injury groups are related to the saturation of the pool of equipment in use, with equipment exhibiting specific characteristics.

The half-life for boots, bindings, and skis is approximately 2.5 years.[29] Critical improvements in bindings began in the early 1970s with no appreciable changes after 1980.[29] Modern guidelines for the installation and service of the boot, binding, and ski system began in the early 1980s. By the late 1980s, the equipment in use was as good as it was going to get.

The equipment development process and its influence on the production of new injury mechanisms worked in reverse for the ACL. Modern boots and skis with superior support and control properties entered the market in the mid- to late 1970s. These design characteristics improved the quality of the skiing experience and facilitated an acceleration in skill acquisition, saturating the pool of equipment by the early 1990s. However, these same qualities restricted the free range of motion of the ski relative to the skier and thereby increased the range of situations that put the ACL at risk.[16,17] Now that the incidence of lower leg injuries and ACL sprains is improving, the challenge for researchers is to identify the factors most responsible and to accelerate these positive trends. (For more information go to http://www.vermontskisafety.com/kneefriendly.php.)

MYTH 3

All you need to know is your DIN number and you can adjust your own bindings

DIN is a slang term for *release indicator value*, which is used by the binding technician to inspect and calibrate alpine ski bindings. The indicator scale is defined by an international standard (ISO 9462).[25] For skiing, DIN refers to the German Institute for the Norms (Deutsches Institut für Normung). DIN standards only have relevance within Germany.

The shop technician's first step in correctly calibrating and inspecting the binding is to determine the skier code—a letter code for the release torque recommended for the skier (in newton meters). Input data for this determination include the skier's weight, height, and age, as well as the skier type—a term for the steepness of trails normally traveled by the skier and the speed at which those trails are negotiated.

With the skier code, the technician uses the length of the ski boot sole to determine the initial indicator value to adjust the toe and heel pieces accordingly. The binding is tested for correct release torque with a device that conforms to international standards (ASTM F1061 and F1062).[1] If the measured release torque is within the range prescribed by the skier code, the heel and toe units of a ski boot binding system are deemed appropriate for use. If outside the prescribed range, the binding is adjusted and retested until the results fall within the prescribed range. However, if test results using the initial indicator value fall outside the manufacturer's limit for readjustment, the technician must follow troubleshooting procedures supplied by the binding manufacturer to determine and address the cause of the malfunction. Solutions may range from a simple repair to the replacement of the binding and/or boot.

Blind faith in the validity of the release indicator scale is a practice common in countries that do not recognize or adhere to ISO/ASTM standards, and it has been related to a two- to fivefold higher risk of tibia fractures than that observed in the United States.[27]

The inspection and calibration of alpine ski bindings is a complex process that requires specialized tools, equipment, and a properly trained technician. Skiers, parents, and coaches should not attempt to adjust equipment. (For more information, go to http://www.vermontskisafety.com/vsrfaq8.php.)

MYTH 4

Toe and heel pieces must be set to the same DIN or the bindings will not function properly

The binding technician uses the binding's release indicator to inspect and calibrate the ski, boot, and binding system. *Appropriate retention* is the ability of the binding to retain the boot on the ski during normal skiing maneuvers. Even with new boots and bindings, the final indicator values may differ from the initial indicator values owing to manufacturing tolerances and the inability of a single release value selection table to perfectly predict the performance of every boot-binding combination. If the boot, binding, and ski system do not provide adequate retention, the shop mechanic might have to readjust toe or heel pieces.

Researchers today know a great deal about retention requirements for the toe piece, from decades of field studies involving real skiers.[37,53] However, retention requirements for the heel piece are at best an educated guess. Boot design, ski design, and skiing technique have significant influence on how the heel piece performs.[5] Regardless of its make, model, or age, the heel piece is not capable of correctly interpreting each release/retain situation and may require readjustment to meet the special requirements of the skier.

When a skier experiences an inadvertent release, it is important to determine which unit was at fault. If the ski parts company with the skier and heads in a different direction with the heel piece in the closed (latched) position, the toe piece was probably the culprit. If the skier falls forward with the ski tumbling in the same direction with the heel piece in the open (cocked) position, the culprit was probably the heel piece. If, however, the ski is found where the release took place (or further uphill), the cause for the release may have been poor skiing technique or a mechanical failure of the system.[5]

Inadvertent releases can occur, but they should not be a reason for the skier to tighten the bindings. If the release was unnecessary, the problem should be discussed with an experienced and properly trained technician. If no technical fault can be found and skiing technique is not an issue, the skier and the technician may need to reevaluate the release settings.

Release settings can be adjusted by changing the skier type (1-3; ASTM F939),[1] which is prominently displayed in ski shops that sell, service, or rent alpine ski equipment. Today's standards allow the skier to select a different classification for the toe and heel pieces for more retention. Reclassification of skier type results in a readjustment and retesting of the bindings by the technician. Increasing the skier type by 1 category has the effect of increasing the release torque by approximately 15%. (For more information, go to http://www.vermontskisafety.com/vsrfaq8.php.)

MYTH 5

Formal ski instruction will make you safer

In the majority of studies done in North America and Europe, skiing lessons did not decrease the risk of personal injury.[3,4,18,20,30,34,58] From the earliest studies[18,30,58] to the present,[3,4,20,34] researchers have shown that lessons are not an effective method for reducing injury risk. In contrast, Ekeland and colleagues have reported that ski instruction in Norway was associated with fewer injuries, when comparing an injured population with an uninjured control group.[9-11]

The focus of current skiing lesson methodology is on rapid skill acquisition with little or no attention to safety or injury prevention, similar to automobile driver education in the United States, which may be counterproductive by increasing exposure and engendering overconfidence.[6,43,62,64] This approach is different from aircraft pilot education, where the emphasis is on situational awareness learning: how one gets into trouble (a stall), where stalls occur, and what recovery methods are available (CEJ Hartel, K Smith, C Prince, unpublished data, April 1991; DC Merket, M Bergondy, H Cuevas-Mesa, unpublished data, March 1997).[46] In pilot training, stall recovery is taught as a kinesthetic response rather than an academic exercise. In driver education, would-be drivers are told what to do in the event of a skid: ease off the gas, do not hit the brakes, and turn in the direction of the skid if possible. They are not taught these maneuvers on a skid pad or other safe location where rehearsal leads to instinct. Both driver education and skier instruction follow a similar approach and so require safety and injury prevention instruction before positive results are seen.[58] A good example of situational awareness in skiing derives an ACL awareness training program, which stresses a kinesthetic learning process.[17] In an experimental study without randomization, ski patrollers and instructors benefited from viewing video footage of real ACL injury events.[17] Then, using a process called *guided discovery*, 4000 participants were asked to plan strategies to avoid ACL injury. For ski patrollers (the highest risk group among ski area employees), there was a 76% reduction in incidence of severe knee sprains, compared to a similar group who did not receive the training. Ski instruction could have an impact on the risk of ACL injury if instructors teach the skiing public how to safely recover from off-balance situations—namely, by sitting down when recovery is not appropriate (see Myth 9). Unfortunately, this program has not been implemented on a large scale for the general public.

MYTH 6

The shorter the ski, the less the torque applied to the leg in a fall—that is, very short skis do not need release bindings

Skiboards are alpine skis, usually 80 to 90 cm long, that incorporate conventional ski boots with nonreleasable bindings. They were introduced around the world in the mid- to late 1990s, and the designers and manufacturers assumed that releasable bindings would not be required, because the skis were very short. Several case-control studies have demonstrated a three- to twentyfold increase in the incidence of ankle and tibia fractures for skiboarders, compared to that of users of traditional alpine equipment, with the overall injury rate the same or lower.[21,22,26,33-35,55] Sakamoto and Sakuraba observed an overall fracture prevalence twice as high for skiboarders than for alpine skiers (with the lower leg constituting 39.6% of all skiboard fractures).[50] Several studies described skiboards as being unnecessarily risky in regard to ankle and tibial injuries.[26,34,55] Langran suggested using releasable bindings on all short skis because of the high probability that the increased risk of lower leg fractures is due to the nonreleasable design of the skiboard binding.[33] The ski industry has had experience with short skis with releasable bindings as far back as the early 1970s. Conventional releasable bindings on very short skis may not prevent low transverse fractures of the tibia in forward falls, but they may prevent a spiral fracture of the tibia.[51] The present literature suggests that skiboards with nonreleasable bindings have an unacceptably high risk of fracture to the tibia and ankle regions and should thus be avoided.

The risk of ACL ruptures is markedly diminished among skiboarders when compared to skiers using traditional length skis.[26,35,55] This fact helps substantiate the contention that most ACL ruptures in alpine skiing are not preventable by modern alpine skiing bindings even when they are functioning perfectly.[17] The most common mechanism of ACL injury has been termed the *phantom foot*.[17] The risk of ACL injury in skiboarding has decreased because the portion of the ski (the tail) associated with the phantom foot scenario has been shortened.

For those who chose to use very short skis, a broad selection of compatible release bindings is available. Nonrelease bindings should not be an option for skis of any length.

MYTH 7

Young bones bend rather than break, so there is no point in spending a lot of money on children's equipment

Young children were found to have a lower overall injury rate than older children.[15,17,23] Unfortunately, the rate and frequency of lower extremity fractures is much higher in children than in adolescents and adults.[2,8,12,19,24,44] Small bones in young children are susceptible to the forces and moments applied to them by an alpine ski during a fall. The reason is multifactorial, but old, poorly serviced, and improperly functioning ski, boot, and binding systems are part of the problem.[8,20,44,59,63] Children with appropriately functioning equipment have a lower rate of lower leg injury than do children with improperly functioning equipment.[8,20] The high rates of children's tibia fractures in Norway were attributed to the bindings—namely, that they were set too high[12,14,15]—thereby suggesting that the lower rates of leg fracture reported in the United States may be a result of adherence to the standard ski shop practices advocated by ASTM International (ASTM F1063 and F1064).[1,8,14]

Young children need the best possible equipment available, which needs to be serviced regularly and appropriately as well as inspected and calibrated according to present standards (ASTM F1063 and F1064).[1] In the past, the quality of children's bindings had lagged behind that of adults, but this is no longer an issue if children's bindings are current.

MYTH 8

When buying boots for children, leave plenty of room for their fast-growing feet

Poor boot fit is a major factor leading to lower leg fractures and sprains, especially among children.[8,16] If the foot can easily move within the boot, then the binding release function is compromised. Children have a greater risk of these injuries and therefore need the best-fitting equipment. That does not mean buying new equipment every year. Well before the beginning of each ski season, a shop technician who is familiar with boot sizing can properly fit the child's feet, often from boots available from the skier's friends and neighbors. A simple commonsense way for parents to determine a proper boot for the child is to remove a given boot's liner and have the child try it on. If it is close to a good fit, then it is back to the shop to have a professional check the boot, binding, ski, and skier to make the necessary adjustments.

Another solution is to use a seasonal rental from a shop that is well staffed and properly equipped. The shop's technicians should follow industry guidelines, treating a seasonal rental just like a new equipment sale.

Parents should not accept boots that are too large, and they should not try to make up for a bad fit with an extra pair of socks. (For more information on boot fitting, go to http://www.gearingtogo.com and click on the *Boots* video clip.)

MYTH 9

If you think you are going to fall, just relax and let it happen

Skiers who do not have a well-practiced plan for the falls that they routinely experience should imagine the posture of a parachutist just before landing and keep every joint in the body flexed moderately. Keep feet together. Keep chin against chest. Do not land on a hand, but keep arms up and forward and be prepared to use the arms to protect the

face and head.[17] Muscles of the extremities and trunk should strongly contract during a fall; this response will stiffen and protect bones and joints.[40,41,66,67]

After the fall, skiers who do not immediately stop should get into a position that allows them to see where they are going. Skiers who attempt to stop themselves by engaging their skis should resist the instinct to fully straighten their legs. It is also important for skiers to not get up until they have stopped sliding and to remember "When you are down—stay down." After stopping, skiers should remember as much as they can about how well they executed their plan and how they can improve their response in the future.[17] Over time, their falling technique should become as expert as their skiing technique. (For more information, go to http://www.vermontskisafety.com/kneefriendly.php and http://www.vermontskisafety.com/vsrfaq7.php.)

MYTH 10

Exercise is the best way to avoid skiing-related injuries

Almost every ski season, popular skiing magazines publish information on conditioning that can reduce the risk of injury. Several prominent orthopaedic authorities have advocated conditioning to reduce the risk of skiing injuries as well.[24,48,61] Others have advocated conditioning programs for skiing safety but admit that no solid proof exists.[31,32,36] In spite of all the advice, there is no convincing evidence that conditioning of any type can reduce the risk of alpine skiing injuries.[4,47] There are, however, conflicting data concerning the effect of fatigue on injury occurrence.[23,39,44,68] Whereas weakness of the thigh musculature may be related to anterior cruciate injuries among alpine skiers, strong muscles have not been shown to prevent these injuries in world-class skiers.[13] In an analysis of well-trained alpine racers at the 1994 Winter Olympics, 42% of the females and 10% of the males had suffered an ACL rupture.[13] With no downside to overall good physical condition, common sense would support conditioning to improve the enjoyment of alpine skiing. Well-prepared skiers will probably get in more runs with less fatigue and will probably be better prepared for the rare emergency requiring strength or endurance.

MYTH 11

Tighter standards that mandate lower release settings will reduce the risk of injury to the ACL among skiers

The current ski-binding recommendations are the result of decades of work and research that have culminated in the current process that seeks to minimize both potential failure modes (and their associated risks): the failure to release and the failure of inadvertent release.[56] This system works, and it is part of the reason injuries in skiing are at an all-time low today.[1,29] If a skier's equipment has been properly inspected, tested, and adjusted in accordance with national and international standards,[1,25] the risk of any injury is about 1 per 516 days of skiing.[29] The risk of an injury owing to release failure or inadvertent release are roughly equal, each about 1% of all injuries.[56] If the binding release value were lowered, it would likely result in a much larger increase in inadvertent release injuries.[56]

Current binding systems are designed to prevent bending and twisting injuries to the midshaft region of the tibia and not the knee.[57] A common but mistaken belief is that the risk of serious knee injuries could be reduced if the release values were lower; however, the primary injury mechanism for the ACL injury is not related to binding function.[17] Thus, any reduction in the binding release values would not result in fewer ACL injuries but would rather increase the number of inadvertent releases.

In conclusion, research supports current recommendations for optimal binding settings, and there is no proof that lowering the setting would yield a lower ACL injury rate.

MYTH 12

Buying new ski equipment is safer than renting

Rental equipment is generally as safe, if not safer, than new equipment. When new equipment has been properly assembled, inspected, adjusted, and tested in accordance with national and international standards, it is very safe.[1,25] However, once equipment leaves the ski shop, its effectiveness begins to decline. A skier should have his or her equipment checked by a qualified ski shop at least once per season, if not more often.

The injury rate for rental equipment is higher than that for user-owned equipment because the former is most often used by entry-level skiers.[52] However, the rental shop should constantly be inspecting rental equipment, if the facility is following proper procedures.[1] Shop technicians should inspect equipment each time it is put into service. The measured release value should be tested during the season in accordance with US guidelines (similar to ISO 9000 standards for quality management systems).[25] This methodology has been proven to ensure quality in any process.

The ASTM standard for rental shop practices (F1064) was adopted in 1987.[1] The development of the standard's proposals was based on an evaluation of injury rates before and after the introduction of new equipment and procedures. One ski area–based rental shop in New England presented data at the New England Bioengineering Conference in April 1973 (unpublished) indicating that there were no lower leg fractures during the winter of 1972-1973, although 4 were expected based on the prior season.

In the fall of the same year, another properly supervised rental facility reported no leg fractures. Based on the prevalence of lower leg fractures in the general skiing population at the ski area (9.3%), 11 lower leg fractures were expected over the following 6 winters (ending in the spring of 1979). However, the facility experienced no such injuries during that time. In the spring of 1979, the rental shop was dismantled and reorganized by new management using the same types of equipment but

without the experimental procedures. The prevalence of lower leg fractures in the general skiing population at the ski area was 4.7%. Over the next 5 winters (ending in the spring of 1984), 9 lower leg fractures were expected at the reorganized facility, with 12 actually occurring. The study demonstrates the value of the procedures eventually published in ASTM F1064.[1]

In summary, rental equipment can be as safe as, if not better than, new or user-owned equipment, providing that the ski shop follows applicable standards.

CONCLUSION

Everyone who advises skiers on methods to help reduce the risk of injury should be certain that the advice given is true and accurate. Many of the positions advocated in the preceding 12 statements are simply untrue and have the potential to cause harm.

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