

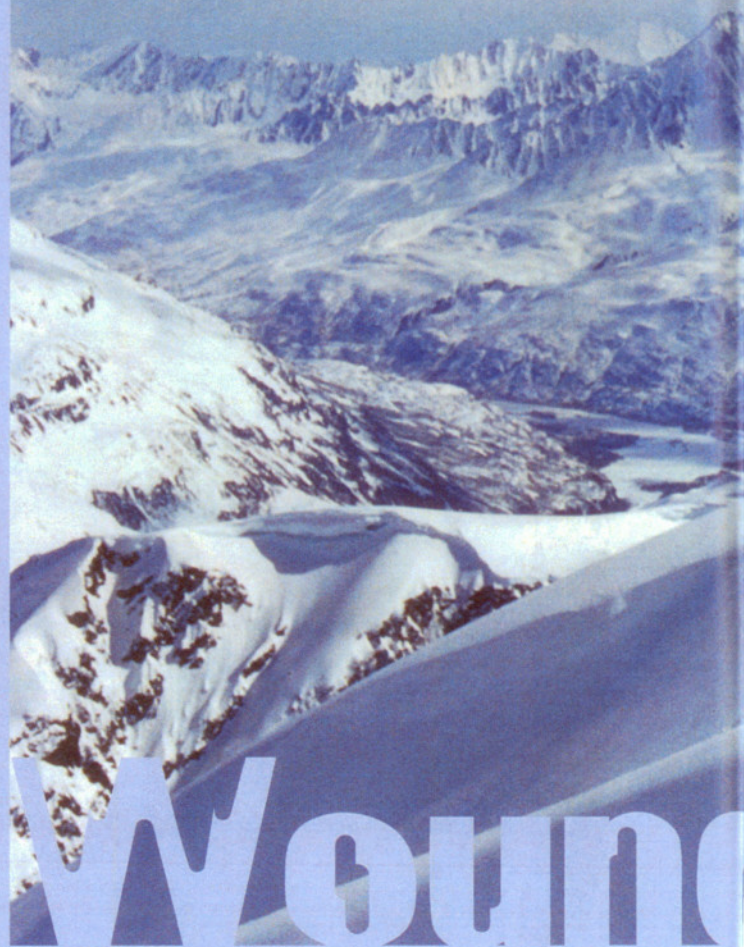
After three days of a continuous storm, the clouds finally parted and the resort glistened under acres of sparkling snow. For the first time in their lives, your clients were going to experience the thrill of deep powder.

The group hooted and hollered as they glided their way down the untracked slopes. And then suddenly, it happened. One woman took what appeared to be a simple fall. But she wasn't getting up. She complained of excruciating knee pain. When the ski patrol arrived, they suspected that she had injured her anterior cruciate ligament, or ACL. In an instant, the day was ruined. Your client's vacation was cut short. And you lost a wonderful customer for the rest of the season.

Few of us like to dwell on the prospect of getting injured when we head out for a day of skiing. That would be a bit morbid. However, with the declining state of fitness in adults and recent evolutions in ski equipment, you and your guests may be at more risk for injury than you might realize.

MODERN BINDING MECHANISMS with their improved release capabilities, certainly help protect the lower leg against injury—provided the binding is properly adjusted. However, one somewhat discouraging factor is the widely held belief that binding settings are made based on the ability of the mechanism to resist fracture to the tibia, not injury to the knee.¹ What's more, today's high-back boots are one of the chief contributors to knee injuries. Since there's no "give" at the ankle, the force of any impact continues up the lower leg until it finds a weak spot: the knee.

Doctors have spent the past several decades studying the anatomy of the knee and conducting research about the mechanisms of ACL injuries in sports such as skiing. From physiological conditions that are out of the skier's control to athletic techniques that can be used in training, skiers are better prepared to understand and recognize the risks and change habits accordingly to avoid injury.



BY ALLEN R. SMITH

A Little History

Since 1972, the research team of Robert J. Johnson, M.D., Carl Ettlinger, and Jasper Shealy have tracked skiing injuries at a sampling of resorts throughout the country, and have provided the most comprehensive data on skiing injury trends in the United States.² They report that the incidence rate for all skiing injuries declined by 44 percent between 1972 and 1994, with the majority of the decline occurring between 1972 and the mid-1980s.

The rate of knee injury is estimated to be between 20 and 36 percent of all skiing injuries, with most knee trauma occurring to soft tissue.³ Johnson and Ettlinger reported a 228 percent increase in grade III sprains of the knee (associated with tears in the soft tissue and joint instability) between 1972 and 1994.² And work by Jarvinen, et al demonstrated a 30-fold increase in ACL injuries through the 1980s.⁴ Although the



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number of mild injuries to the knee, such as sprains not requiring medical attention, has declined, the rate of serious knee injuries, such as ACL tears, has increased at an epidemic rate.⁵ This can most likely be attributed to shorter skis and higher back boots.

The Anatomy of the Knee

Before focusing on the issues surrounding ACL injuries, let's review the basic anatomy of the knee. The knee joint is composed of the tibia, fibula, and femur bones as well as numerous ligaments and tendons. The femur is the upper leg bone. The tibia is the larger of the two bones in the lower leg. Ligaments are strong, elastic tissues that connect one bone to another. The ACL is the strongest but least flexible ligament in the knee and connects the tibia to the femur. The role of the ACL is to prevent the tibia from sliding too far forward out of

alignment with the femur (fig. 1, page 18).

An injury to the ACL occurs when it is torn or sprained; generally when the knee is twisted in either a fully extended or hyperflexed position.

Signs, Symptoms, and Causes of Injury

Most people who injure their ACLs describe one or more of the following symptoms: an audible popping sound in the area of the knee joint, the feeling of the knee "giving way," so much pain that they have to halt all activity, and swelling within a few hours of injury.⁶

There are a number of risk factors for injury to the ACL; some predictable, some not. They include anatomical problems of the knee joint, neuromuscular elements, gender differences, hormonal changes in women, and poor skiing technique.

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Anatomical Problems of the Knee Joint

While relatively rare, some skiers suffer from an impingement, or "pinching" of the ACL against the notch at the end of the bones of the leg; either the tibia or femur.⁷ Instead of having a smooth, U-shaped notch that allows the ACL to slide smoothly within the joint, a small percentage of skiers have a narrow, V-shaped notch in which the ligament can get caught, resulting in susceptibility to the bone's shearing forces. Computed tomography (CT) scan analysis has also revealed narrower intercondylar notches (the space between the protuberances at the end of the bone) in some injured patients when compared with those of patients with healthy knees.

Neuromuscular Elements

The balance of power and function between the quadriceps (front of thigh) and hamstring (back of thigh) is crucial to knee stability. "The typical quadriceps/hamstring strength ratio is somewhere around 60/40, whether you're a recreational skier or a world-class athlete," says Michael Torry, Ph.D., director of biomechanics at the Steadman-Hawkins Sports Medicine Foundation in Vail, Colorado. "Interestingly, as athletes become stronger through training, the ratio remains the same, but the power and endurance of the muscle groups increase."

Other investigators have reported that vigorously contracting the quadriceps muscles while the knee is flexed between 10 and 30 degrees significantly increases ACL strain and that contracting the hamstring while in the same position helps to shield against it.⁸

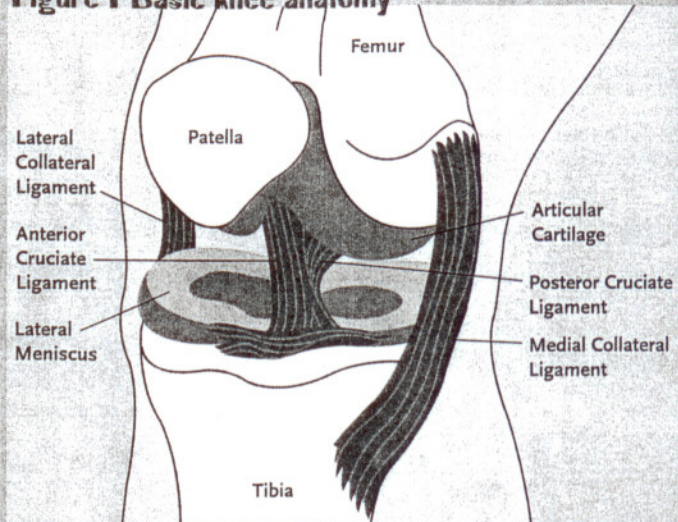
Gender Differences and ACL Injury Rates

"Given equal skill levels, women are 2.5 times more likely to injure their ACLs," says Carl Ettlinger, director of Vermont Safety Research. "Whereas men are more likely to sustain fractures and other blunt-impact injuries."

Research has found that female athletes rely more on their quadriceps muscles and take significantly longer to generate maximum hamstring muscle force than their male counterparts.⁹ Other studies have shown that women have more knee and muscle laxity than men. Therefore, in female athletes with above average hamstring flexibility, the protective ability of this muscle group may be diminished and the forces required to stabilize the knee are transferred directly to the ligaments. Although these elements may not be the primary cause of ACL injury in women, they may predispose female athletes to ACL disruption.¹⁰

Our knowledge of neuromuscular characteristics of the knee is in its infancy. Nevertheless, any factors that favor the quadriceps over the hamstrings, such as unbalanced training regimens may predispose an athlete to ACL injury.

Figure 1 Basic knee anatomy



Hormonal Changes in Women

As stated earlier, non-contact ACL injuries are believed to be more common in women than in men, and this is particularly true among those who participate in basketball, alpine skiing, volleyball, and gymnastics.¹¹

One hypothesis is that any rise in the hormone estrogen, which can relax soft tissue, may predispose female athletes to ACL tears. Estrogen, a hormone with receptors in the ACL, reduces the tensile strength of the ACL during mid-cycle of the menstrual period. In addition, estrogen has been reported to decrease fine motor skills by acting on the central and peripheral nervous systems.¹² Motor skill deficits may diminish the normal neuromuscular protective mechanisms of the knee.

Poor Skiing Technique

Poor skiing technique refers to any bodily alignment or position that predisposes a joint to injury. This includes bad luck. Often, it is poor technique during a fall, not while skiing, that is most threatening. According to Ettlinger, ACL injuries on the ski slope often result not from falling but from an attempt to recover from a loss of balance.¹³ As opposed to, say, running, jumping, or playing soccer, alpine skiing technique sometimes forces the tibia to rotate inward while the knee is flexed past 90 degrees. This position often results when a skier falls backward and catches the inside edge of the tail of the downhill ski. A number of mechanisms of injury can contribute to ACL ruptures, but Ettlinger asserts that there are two major types of falls that are best documented: the boot-induced landing and the phantom foot syndrome.¹⁴

The Boot-Induced Landing

The boot-induced landing is probably the easiest injury to avoid. It typically occurs when the skier begins a jump off balance with his or her weight over the heels. The skier rotates the

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downhill arm up and rearward in an attempt to regain balance before landing. This motion is accompanied by an extension of the skier's uphill leg. When the skier lands, the tail of the uphill ski hits first. As the center of pressure against the bottom of the ski moves forward, the pressure of the boot against the back of the leg increases. At the same time, the muscles of the skier's leg automatically contract to hold the leg in a fully extended position. By the time the portion of the ski under the boot heel hits the snow, there is no laxity left in the skier's legs to absorb the impact and the back of the boot drives the tibia out from under the femur, injuring the ACL.¹⁴ The most important way to prevent a boot-induced landing is to prepare correctly for the jump, know where and how to land, land squarely on both skis, and keep your knees flexed. You could also choose to avoid jumping altogether and keep your skis on the snow.

Boot-induced landings are almost impossible to correct because the skiers are airborne before they realize they're in a precarious position. The key is to ensure that your center of mass is directly over your feet as you leave the snow when initiating a jump.

The Phantom Foot Syndrome

More common than the boot-induced landing, the phantom foot syndrome (so called because the tail of the downhill ski acts like a lever that points in a direction opposite of the foot) affects skiers in three situations. The first occurs when a skier attempts to get up after a fall while he or she is still moving (fig. 2).

- After losing control, the skier falls or sits back between the skis and attempts to recover while the skis are still moving forward.
- As the skier continues to move, the skis begin to spread apart, forcing the skier's knees inward.

- The inside edge of the tail of the downhill ski catches, forcing the lower leg to rotate inward.
- The forced internal rotation strains the ACL, resulting in injury.

The second and third situations occur when a skier attempts to recover his or her balance from an imbalanced position or sits down during a fall (fig. 3).

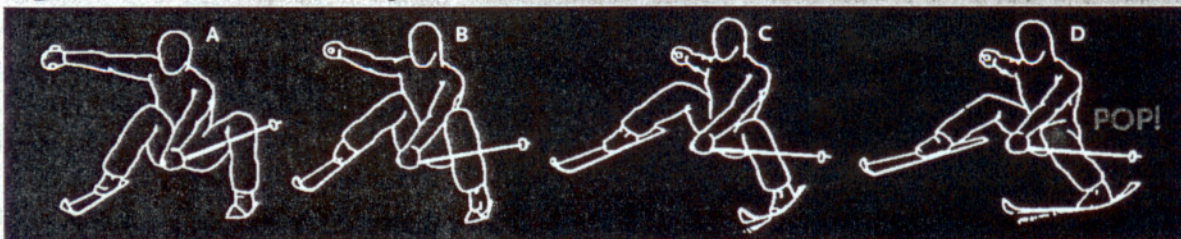
- When a skier gets off balance, he or she instinctively swings the uphill arm backward to try to compensate.
- The skier continues to fall backward toward the tail of the skis.
- The skier begins to sit down in an attempt to stop moving, and drops his or her hips below the knees.
- As the hips drop, the uphill ski comes off the snow.
- With the uphill ski unweighted, the skier's body weight shifts to the inside edge of the downhill ski and forces the knee to rotate inward.
- The upper body twists toward the downhill ski and causes injury to the ACL.

The most effective way to reverse the trend for injury is to immediately employ strategic rather than reflexive, corrective maneuvers. Instead of swinging one arm back or up, push the arms forward to move the center of mass back over the balls of the feet rather than on the heels. With the body weight forward on the skis, move the feet back together and keep the hands square over the skis.

In addition to the boot-induced landing and phantom foot syndrome, there are certainly many other mechanisms of injury that are prevalent but have not yet been thoroughly studied. These include 1) the skier falling forward between diverging

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Figure 2 The phantom foot syndrome while attempting to recover from a fall



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Figure 3 The phantom foot syndrome while attempting to recover after losing control



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ski tips, 2) the skier losing control and falling after another person skis over his or her ski tails, and 3) one skier skiing into the back of another in a "clipping" fashion.

Prevention of ACL Injuries

Now that you've heard the bad news, it's time for the good. There are a number of steps that you and your clients can take to help reduce the risk of injuring an ACL. These include proper conditioning and improved skiing mechanics to minimize dangerous situations.

Conditioning

One popular myth is that pre-season conditioning will make you immune to injury. "Preseason conditioning programs don't reduce knee injuries in alpine skiing," says Robert J. Johnson, M.D., an orthopedic surgeon at the University of Vermont who has published several studies on ski injuries. "Many claims have been made but none have ever been proven. World-class skiers have the highest ACL injury rates, and they're the best trained and the strongest."

Pre-season conditioning will, however, help balance the quadriceps/hamstrings strength ratio, and strengthen small muscles groups, resulting in more stability of the knee.

"While it's impossible to completely prevent injuries to the ACL, there are a number of sound conditioning exercises that you can use to help minimize your risk for getting hurt," says Steve Stalzer, director of therapy at the Howard Head Sports Medicine Center in Vail, Colorado. The Howard Head Center is the physical therapy group for Vail Valley Medical Center and is a provider for the U.S. Ski Team. "Skiers should focus on closed-chain exercises," Stalzer says. "Closed-chain exercises involve both ends of the joint being connected to immovable objects. For instance, a squat or leg press anchors the foot when standing on the ground, while the femur is anchored at the hip joint." Closed-chain exercises increase joint compressive forces and cause more hamstring contraction when compared to open-chain exercises, he says, adding "The effect is increased knee stability and decreased ACL strain." An example of an open-chain exercise is the seated knee extension. For more information regarding pre-season conditioning programs, please check with a licensed physical therapist or your local fitness facility.

Improved Skiing Mechanics

Ettlinger, et al¹⁴ have developed a creative and innovative teaching program that focuses on avoiding the types of falls that commonly cause ACL injuries, especially in beginner skiers.

A study group made up of ski instructors and patrollers who went through Ettlinger's pre-season teaching program was compared with a control group that did not have access to the protocols. The group with the specialized training demonstrated a

62 percent reduction in ACL injury rate. The preseason program focused mainly on what *not* to do when faced with a potential fall and how to avoid the phantom foot syndrome.

In Summary

No one wants to think about getting injured. But skiing, by nature, carries a number of inherent risks. Luckily, these risks can be minimized through proper preseason conditioning and by practicing the described response strategies.

"Some of the most valuable instruction that skiers can receive is how to correctly fall," says Torry. "It's important for skiers at all levels to acknowledge that occasionally, they're going to go down. There's nothing wrong with that."

"Teaching people how to react in hazardous situations should never be linked to the threat of injury," says Ettlinger. "We can keep skiing fun by avoiding threatening terms such as 'ACL,' 'knee injury' and 'sprains' when teaching our clients," he says. Some instructors teach clients how to fall "correctly," while others prefer to steer clear of that discussion. Check with your ski and snowboard school director and consult with other instructors to decide what approach is most appropriate. Often it will depend on the student or class.

As a professional ski instructor, you can play a large role in keeping your students safe through education and awareness. Have fun. Stay safe. And enjoy the powder! ♦

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