Treating Foot Pain in Alpine Skiers with Pes Planus

What role should the podiatrist play?

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Editor's Note: *This article originally appeared in the September 2017 issue of PM; we are reprinting it here because of its uniqueness in the podiatric literature and as a testament to the late Dr. Scherer's impressive legacy of accomplishments.*

The foot plays a unique role in downhill skiing. Subsequently, several of the pathologies that are experienced commonly by skiers are unique to the sport of skiing. The question then arises, whom should the skier consult when experiencing foot pain while skiing?

Many of the pathologies suffered by skiers are simply secondary to poor-fitting boots or lack of support inside the boot. Many of these skiers can benefit greatly by working with an experienced and skilled boot fitter in a ski shop. In fact, most of the problems suffered by skiers can likely best be taken care of by a boot fitter.

There are, however, several conditions commonly experienced by skiers that, in most cases, are best treated by a medical professional who can better diagnose a specific pathology and offer a comprehensive plan of treatment for that pathology.

An example of a common condition that is experienced by skiers and may be best treated by a medical professional (although often in concert with a boot fitter) is Morton's neuroma.

A boot fitter may be able to adjust a boot to reduce medial-lateral compression of the foot inside the boot and produce a foot bed that will help transfer pressure off the ball of the foot.

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A podiatrist, however, can also provide direct treatment of the neuroma—through injections, for example—along with, in many cases, being able to produce an in-boot orthosis that is more effective at transferring pressure off the metatarsal head region.

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Pes Planus

Another condition commonly experienced by skiers, and the one on which this article focuses, is arch pain experienced by the skier with pes planus.

Plantar Intrinsic Stress Syndrome

The most common condition treated in downhill skiers by the author is a complaint of a deep, searing arch pain, often described as a deep ache that happens only when skiing. Invariably, the patients who present with this complaint have a pes planus foot type.

They describe a pain that often starts immediately upon starting to ski, but will worsen with more intense effort such as when skiing steeper slopes or more challenging terrain such as moguls. Usually, the pain is mid-arch and plantar-medial. Much like a compartment syndrome, the symptoms abate when the activity is stopped. It is rare that patients can recreate these symptoms when doing any other activity.

While a compartment syndrome as the root cause of these symptoms cannot be ruled out, it appears more likely that the pain is secondary to overwork of the intrinsics of the arch of the foot. Most likely, it is primarily the abductor hallucis that is involved given the location of the presenting complaint and based on evidence that the abductor hallucis acts to support the medial longitudinal arch. In addition, research by Kelly in 2012 demonstrated that during activities that require increased postural demand, such as downhill skiing, or when single leg stress is attempted, like skiing, the plantar intrinsic muscle activity increases dramatically.[1]

The author has referred to this condition as "skier's myalgia". A more descriptive term is "plantar intrinsic stress syndrome".[2]

Ski Turn Mechanics

To understand the etiology and treatment of plantar intrinsic stress syndrome, it is important to understand the mechanics of a ski turn. A properly executed alpine ski turn consists of the ski edge "carving" into the snow. Carving a ski turn requires two primary skills: rolling the knees and the ankles inward (downhill) and keeping the weight forward. A carved ski turn has three parts:

- Initiation: The start of the turn
- Shaping: Where most of the actual carving happens
- Finish: At the end of the turn is the finish where the skier dials back the power to prepare for the next turn

In the initiation phase, rolling of the knees and ankles starts by having the skier aim the knees down the hill and rolling onto the area of the hallux and the first met head of the new downhill foot as the skier starts to put weight on that ski and engages the ski edge into the snow.

Through the shaping of the turn, the skier drives his knee toward the toe piece of the binding. That force transfers through the boot and on to the ski, bending it and carving the edges. The more pressure on the boot, the tighter the turn; and the more rigid the foot, the more efficient is the transfer of force from the boot to the edge of the ski.

Rigid Feet Allow Efficient Transfer of Force to the Edge of the Ski

The best alpine skiers tend to have rigid feet. This was described by Kirby and Roukis as "medial column dorsiflexion stiffness."[3] Having little motion of the foot inside the boot allows for very efficient transfer of force on to the edge of the ski as soon as the knees and ankles begin to roll in downhill.

What Is a "Bad Foot" for Downhill Skiing?

One of the worst types of feet for a downhill skier is one that is excessively flexible. This was described by Kirby and Roukis as "low medial column dorsiflexion stiffness".[3]

In this foot type, the medial forefoot will simply dorsiflex with increasing plantar force acting on it. Skiers with low medial column stiffness will have difficulty initiating and maintaining a ski turn since they will have difficulty generating adequate force on the medial edge of the ski. To compensate for the unstable foot and difficulty in maintaining an edge, they will internally rotate and adduct their knee excessively to try to get the medial forefoot to generate enough force on the boot.

When the skier is unable to achieve an adequate edge through transfer of force by rolling in of the knee and the ankle, then the intrinsics of the arch of the foot are forced to fire excessively to try to stabilize the foot and achieve that edge. This seems to be when these skiers experience the searing arch pain known as plantar intrinsic stress syndrome.

Weak Intrinsics in the Pes Planus Foot

This is complicated by the fact that in pes planus feet, there is evi-

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dence that the intrinsics tend to be weak.

Angin and associates in 2014 used ultrasound to evaluate the cross-sectional area of the peroneus longus and brevis, flexor hallucis brevis, flexor digitorum brevis, and the abductor hallucis in 49 adults with normal foot posture and 49 adults with pes planus feet.

The results show that the cross-sectional area and thickness of the abductor hallucis, flexor hallucis brevis, and the peroneal muscles were significantly smaller and the flexor hallucis longus was significantly larger in the pes planus group.

Their conclusion was that the greater cross-sectional area and thickness of the extrinsic muscles might reflect compensatory activities to support the medial longitudinal arch if the intrinsic foot muscle function had been compromised by altered foot structure.[4]

Treatment of Plantar Intrinsic Stress Syndrome in Downhill Skiers with Pes Planus

The treatment of plantar intrinsic stress syndrome in downhill skiers is focused on two primary areas:

1) Stabilization of the feet with proper orthotic devices

2) Strengthening of the intrinsic musculature, in particular, the abductor hallucis

Foot Orthoses for Downhill Skiers with Pes Planus

Regardless of the pathology, there are several basic tenets that must be followed whenever writing foot orthosis prescriptions.

Tissue Stress Theory

The tissue stress theory is a practical and arguably the most commonly used method of writing prescriptions for foot orthoses. Even those practitioners who have never heard of the theory will use it in that in writing the orthotic prescription, the goal is to design an orthotic device that reduces abnormal stress that is leading to pain or tissue damage. The tissue stress theory has three main components:

1) Identify the structure which is injured or symptomatic.

2) Determine the most likely type of abnormal tissue stress that's causing the pathology.

3) Prescribe a specific orthosis that reduces that abnormal tissue stress.[5]

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In the situation of treating a downhill skier with low medial column stiffness resulting in plantar intrinsic stress syndrome, the goal of foot orthotic therapy is to effectively increase the medial column stiffness so that pressure can more effectively be transferred to the medial edge of the ski. This will theoretically reduce the need for firing of the intrinsics to achieve a medial edge and carve a turn. This, of course, should help reduce the pain that occurs due to over-firing of the intrinsics.

In a regular shoe, such an orthosis may include a number of features that will help shift force medial to the subtalar joint axis in order to increase supinatory torque around that axis.[6] These features might include a deep heel cup, a medial heel skive, a medial flange, a minimal cast fill, and use of a rigid or semi-rigid material.

Ski boots, however, place significant restrictions on the size of an orthosis that can be produced. The narrow heel pocket of modern ski boots severely restricts the height of a heel cup that will fit into the ski boot.

In fact, it can be so difficult to fit an orthosis with any sort of heel cup into an orthotic, let alone a heel cup deep enough to be clinically effective, that we have found that the most effective ski orthotics have no heel cup at all.

Instead of a standard orthosis with a heel cup and rearfoot post, there is simply a flat portion of the orthosis under the heel.

Support of the foot (and subsequent increase in medial column stiffness) is then gained through a minimum cast fill orthosis so that the device conforms very closely to the arch of the foot and then incorporation of a medial flange so that the orthosis supports the entire medial longitudinal arch.

One issue that is commonly found in foot beds that come from ski shops is they are not adequately wide enough for the pes planus foot type. When the foot bed is not the full width of the foot, it will severely limit the ability of the device to support the foot and essentially provide greater medial column stiffness. The recommended custom ski orthosis for the skier with pes planus incorporates a medial flange so that the orthosis supports the entire width of the foot. Figure 1 shows the shell of such an orthosis.

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If the heel is significantly everted and additional supinatory torque is necessary to be added later, a varus wedge can be added on top of the heel portion of the orthosis. This is demonstrated in Figure 2. The wedge, unlike a heel cup, will not limit the ability of the orthosis to fit back into the heel of the boot.

In addition, an "extrinsic medi-

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al heel skive" can be added to the liner of the boot as shown in Figure 3. These two modifications can help shift the center of orthotic reactive force being applied to the foot farther medially, thus increasing the supinatory torque around the subtalar joint axis.

If a forefoot varus or forefoot valgus is present, particularly a structural fore-foot varus, then a cover should be added along with a forefoot varus extension on the orthosis.

Figure 2: Orthosis with varus wedge added on top of the heel portion

Intrinsic Strengthening

In 2008, Headlee and colleagues performed EMG studies that demonstrated that the abductor hallucis (AbH) functions to support the medial longitudinal arch and helps to control pronation during static stance. Therefore, it has been suggested that strengthening and thus improving the endurance of these intrinsic foot muscles, particularly the abductor hallucis, may reduce over-pronation and the subsequent pathologies.[7]

In a 2014 study, Kelly, et al. measured EMG activity in abductor hallucis, flexor digitorum brevis, and quadratus plantae muscles under varying loads. As the load increased, the longitudinal arch height decreased, and this resulted in increased EMG activation of the plantar intrinsics. Researchers also found that as the plantar intrinsics were stimulated, the longitudinal arch height increased. These studies show that the plantar intrinsics can supinate the subtalar joint and raise the longitudinal arch in response to increased foot loading.[8]

Figure 1: Orthosis with medial flange

How to Strengthen the Plantar Intrinsics

In a 2011 study, Jung, et al. ran a comparison of the muscle activity of the abductor hallucis and the medial longitudinal arch angle during both toe curl and short foot exercises. Their results showed that the EMG activity of the abductor hallucis was significantly greater in the short foot exercise than during the toe curl exercise. These results suggested that the short foot exercise is a more useful strengthening exercise than toe curl exercises in activating the abductor hallucis muscle.[9]

In a related study, the same primary researchers evaluated the effects of foot orthoses and a short-foot exercise intervention on the cross-sectional area (CSA) of the abductor hallucis muscle and strength of the flexor hallucis in subjects with pes planus. Subjects were assigned to either a foot orthosis group or a combined foot orthosis and short foot exercise group.[10]

Both groups showed that the cross-sectional area of the abductor hallucis and the strength of the flexor hallucis increased significantly. But it showed that foot orthoses combined with short-foot exercise is more effective in increasing the CSA of the abductor hallucis muscle and the strength of the flexor hallucis compared with foot orthoses alone. Their conclusions were that the study demonstrated that foot orthoses combined with short foot exercise is effective in increasing the cross-sectional area of the abductor hallucis muscle and the strength of the flexor hallucis compared with foot orthoses alone. Therefore, foot orthoses combined with a short foot exercise are recommended for improving the strength of the abductor hallucis muscle in subjects with pes planus.

Figure 3: Boot liner with extrinsic medial heel skive

Based on these studies, it's recommended that skiers prone to plantar intrinsic stress syndrome begin a progressive intrinsic strengthening program using the short foot exercise several months prior to ski season.

A proposed progressive plan for strengthening the intrinsics follows:

- Begin the program two months prior to ski season.
- Continue the exercises through the ski season if not skiing more than once a week.
- Spend five to ten minutes per day on the exercises.
- Begin the program with the patient sitting in a low chair and performing the short foot exercise one foot at a time.
- When the patient can perform the short foot exercise on one foot while sitting for five minutes, then perform the short foot exercise on both feet simultaneously.
- When able to perform the short foot exercise easily on both feet sitting, the patient stands and performs the short foot exercise on one foot at a time.
- When one foot standing can be performed easily for 5 minutes, then do two feet at a time while standing.
- Finally, stand and perform the short foot exercise while balancing on one foot.

Those who experience foot pain when skiing are most often first seen by ski shop boot fitters. If skiers have pain that is not relieved by a boot adjustment, they should receive a

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medical diagnosis and a comprehensive treatment plan.

Plantar intrinsic stress syndrome is just one example of a pathology experienced by skiers that is best treated by a podiatrist who understands the role that foot biomechanics plays in this specific sport and can provide a comprehensive plan to address the issue. **PM**

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For over 40 years **Dr. Scherer** made significant contributions to the podiatric community, most notably in podiatric education. In addition to teaching foot and ankle biomechanics in the classroom, he lectured nationally and internationally, authored numerous scientific articles and the popular text *Recent Advances in Orthotic Therapy.* Dr. Scherer held several academic positions at the California College of Podiatric Medicine and was Clinical Professor at the College of Podiatric Medicine, Western University of Health Sciences. In 1989, Dr. Scherer co-founded ProLab Orthotics. He passed away unexpectedly in 2018, leaving a legacy of accomplishments and high standards of education for future generations of podiatrists.