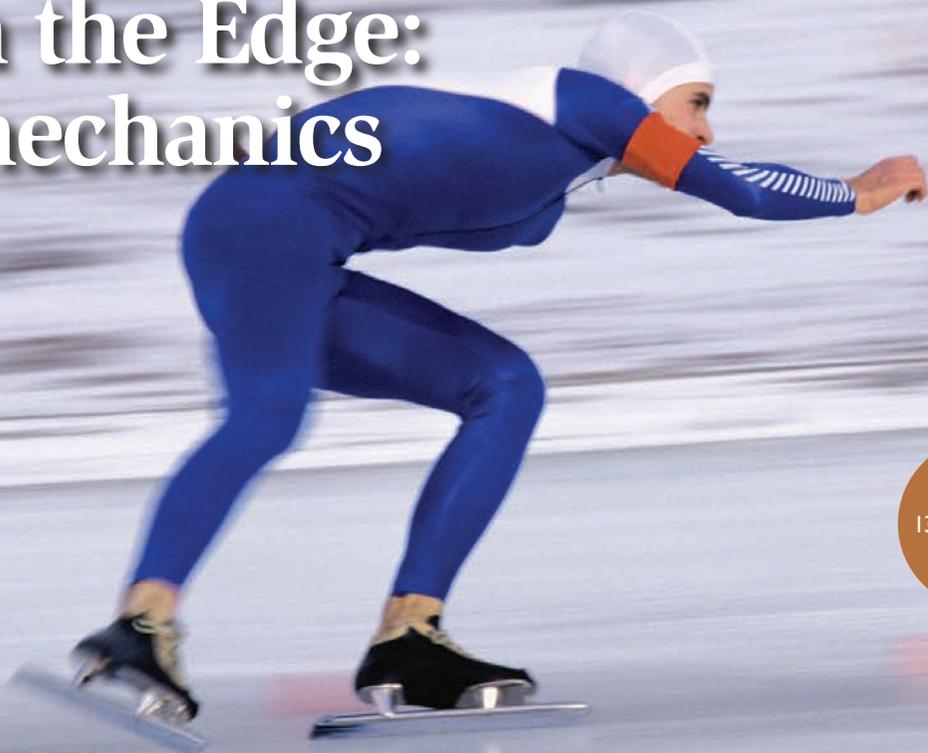




Living on the Edge: The Biomechanics of Power Skating

There are some very specific overuse injury patterns seen in the ice hockey population.

BY R. NEIL HUMBLE, DPM



Ice skating in all its various forms has shown increased popularity worldwide. Olympic speed skating champions are coming from areas of warm climate and ice hockey teams are starting up in almost every populated geographical location. A close cousin to ice skating is in-line skating, which is a similar biomechanical activity and is another common recreational and fitness endeavor. The increasing popularity of skating makes it likely that all podiatric practitioners will benefit from a fundamental understanding of the management of this athletic population, regardless of practice location.

Ice skating involves three disciplines: figure skating, speed skating and power skating. It is power skating that defines the unique skating patterns and mechanics of locomotion seen in ice hockey. The principles of podiatric biomechanics can be applied to all of these

skating disciplines, as many of the mechanics of foot position and balance are similar. For the purposes of this article, however, I will focus on the biomechanics of power skating (Figure 1).

of power skating. The podiatric assistance in foot and lower extremity balance on top of a narrow balance point, the skate blade, will allow a practitioner to assist in both improved perfor-

**Both walking and skating
are biphasic movement patterns that consist of periods
of single and double-limb support.**

Biomechanics

Power skating in hockey involves skating forward, backward and with multiple directional changes as the game evolves. It is this ever-changing movement pattern that makes this activity difficult to study from a biomechanical standpoint. It is forward acceleration and striding, however, that are the most consistent and studied aspects

of power skating and overuse injury patterns.

In order to better understand the biomechanics of power skating and the clinical injury perspectives that may arise, it is first helpful to compare power skating with the more commonly understood biomechanics of walking. Both walking and skating are biphasic movement patterns that consist

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of periods of single and double-limb support. By comparison, it is the support phase of walking that becomes the skating glide. One aspect of skating that makes it unique in the support phase is that the friction on the performance surface is much less than that seen in most walking activities. As a result there are decreased posterior linear shear forces with touchdown due to decreased friction and decreased anterior linear shear forces in the late midstance to propulsion stage. This low friction surface will necessarily impart a need to abduct the foot by external hip rotation at propulsion.¹ The center of gravity therefore does not progress in a linear sinusoidal path over the foot as seen in walking, but rather the skater and his/her center of gravity move in an opposite direction to the weight

bearing skate.

The acceleration in power skating is divided into two unique stride patterns, the first three strides and the fourth stride, known as the typical skate cut.²

The first stride pattern usually involves the first three strides (Figure 2). It lasts approximately 1.75 seconds, involves continual positive acceleration and has a negligible or non-existent glide phase.³ It is during this stride pattern that the skater often appears to be “running” on his/her skates.



Figure 1: Ice hockey, power skating

sion through full knee extension, hyperextension of hip and plantar flexion of the ankle.

Clinical Injury Perspective

Without a doubt the most common foot and lower extremity injury patterns seen in ice hockey are acute traumatic events. However, for the purposes of this article we will focus on the more common presenting problems in an office setting. There are, first, the common dermatologic conditions seen in this patient population. Second, there are the intrinsic foot-to-boot injuries that can be precipitated from the nature of the unique footwear, and last, there are the specific biomechanically-produced clinical injury patterns that may arise from overuse.

A general understanding of skate anatomy and fit is necessary for a full understanding of the impact of common podiatric pathologies, as well as for an understanding of the biomechanically-produced overuse injuries seen in the skating population (Figure 4). There is first the skate boot that is rigid for protection and support.

Sewn skates generally fit one to one-and-a-half sizes smaller than one's regular shoe size. Skates need to fit snugly and toes should “feather” the toe cap. All boots have a heel raise that may be from five degrees to nine degrees but can vary from one manufacturer to another. Next is the blade housing that is riveted or screwed onto the boot itself. The attachment of

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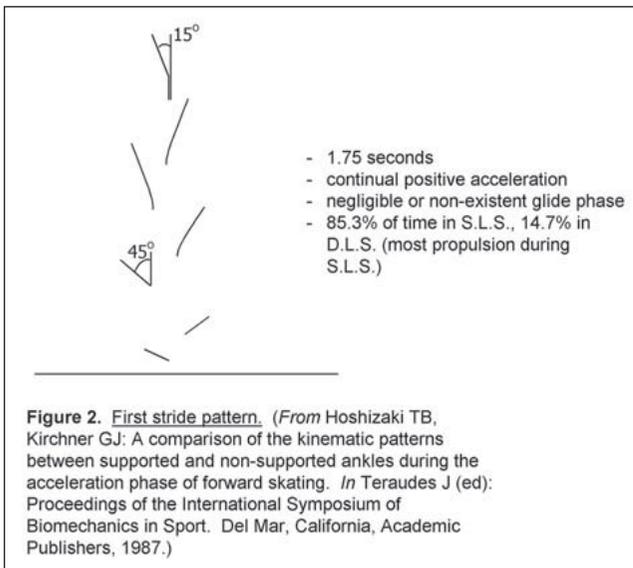


Figure 2. First stride pattern. (From Hoshizaki TB, Kirchner GJ: A comparison of the kinematic patterns between supported and non-supported ankles during the acceleration phase of forward skating. In Teraudes J (ed): Proceedings of the International Symposium of Biomechanics in Sport. Del Mar, California, Academic Publishers, 1987.)

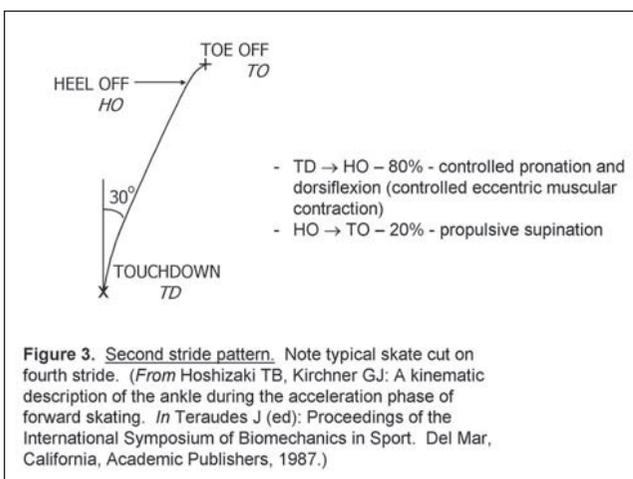


Figure 3. Second stride pattern. Note typical skate cut on fourth stride. (From Hoshizaki TB, Kirchner GJ: A kinematic description of the ankle during the acceleration phase of forward skating. In Teraudes J (ed): Proceedings of the International Symposium of Biomechanics in Sport. Del Mar, California, Academic Publishers, 1987.)

The second stride pattern often begins on the fourth stride and is considered the typical skate cut² (Figure 3). This stride pattern consists of periods of positive and negative acceleration and involves three phases. It starts with a glide during single limb support which imparts negative acceleration.⁴ It continues with propulsion during single limb support which is accomplished by external rotation of the thigh and the initial extension movements of the hip and knee.⁵ This stride pattern concludes with propulsion during double limb support.

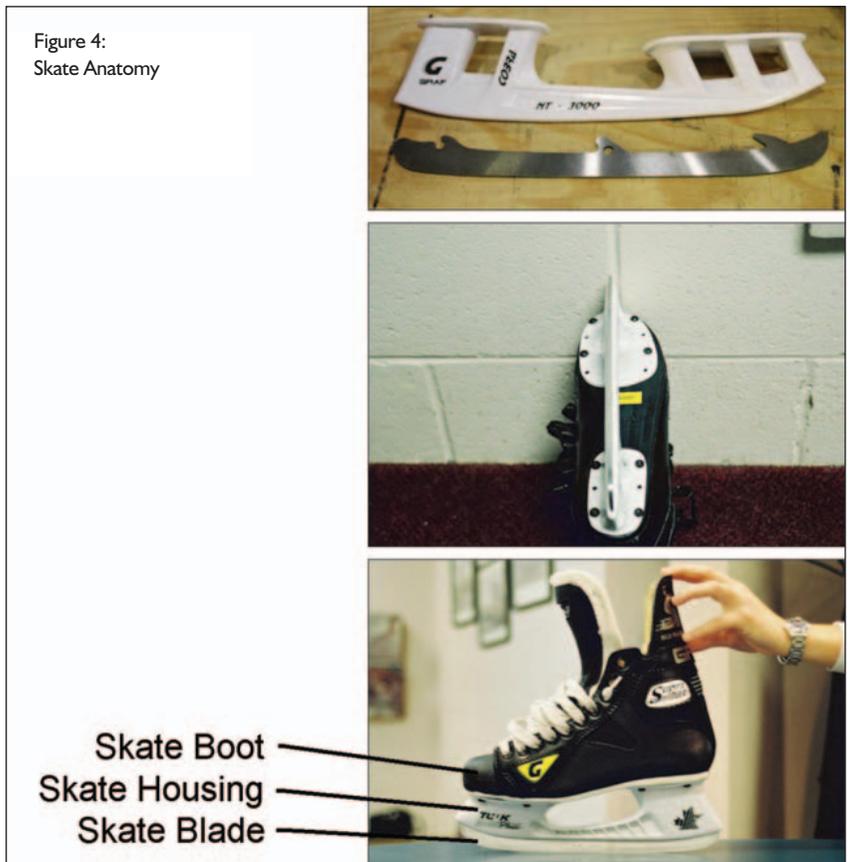


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the blade housing to the boot can be a point of biomechanical input. This housing can be moved medial to lateral, or anterior to posterior on the boot. Its standard position is to hold the blades centrally under the heel to continue forward under the second metatarsal head and further forward through the second digit. The blade housing can also act as an attachment site for heel lifts and wedges as they are sandwiched between the housing and boot. Lastly is the narrow blade, which can also be adjusted for biomechanical effect. It is rockered front to back and is hollow ground on the bottom surface to create a medial and lateral edge or bite angle. The blade acts as a balance point and as little as one inch is all that normally contacts the ice surface (Figure 5).

As mentioned above, skates need to fit snugly, and as such many skaters wear their skates without socks for a better “feel.” This practice should be discouraged due to the dermatological consequences from both friction and hygiene. Blisters, corns, calluses, tinea pedis, onychomycosis, and verrucae are common in this patient population. Use of general podiatric principles along with a thin, well-fitting performance sock with both hydrophilic and hydrophobic properties will decrease friction within the boot and improve hygiene. If thin enough, it will still allow the “feel” needed for performance.

The specificity of the footwear and its need for a performance fit can also cause friction and pressure injuries at the interface between common structural foot deformities and the boot. Common podiatric pathologies such as hammertoes and bunions are a painful dilemma in this footwear and are treated in the usual fashion. Haglund’s deformity, however, is an especially difficult problem for skaters (Figure 6).



Other than traditional podiatric treatments one may alleviate the skate counter pressure with internal or external heel lifts, accommodative adhesive felt padding within the skates, or expansion of the heel counter by a local skate shop. A well-posted custom foot orthotic can also decrease the movement of this prominence within the skate. The tight fit of skates can also increase the incidence of Morton’s neuroma and dorsal superficial compression neuropathies.

Proper boot structure, along with the necessary biomechanics of skating, can decrease the frequency of complaints from certain pathologies. Hal-lux limitus, Achilles tendonopathy and plantar fasciitis are all less commonly a

problem during skating activities.

Biomechanically-produced overuse foot and ankle clinical injury patterns can clearly be identified in ice skating. The narrow blade or balance point creates need for strenuous eccentric muscle control and proprioceptive skills to assist in balance over this small balance point. As a result, general foot fatigue from strain of the small intrinsic muscles of the foot are common. As well as the intrinsic muscle strains, there are the extrinsic tendonopathies that can occur in the posterior tibial tendon and the peroneal tendons and muscles as a reaction to the need for balance.

In comparison to other sporting activities, power skating shows a decrease in the number of contact phase injuries due to the low friction of the ice surface. The overuse injuries in the lower extremity usually show up more proximally in the groin or low back due to the inherent need for skate and skater to be moving in opposite directions as propulsion occurs. Groin injuries in the adductor muscle group (adductor magnus, longus and brevis) occur when the thigh is externally rotated

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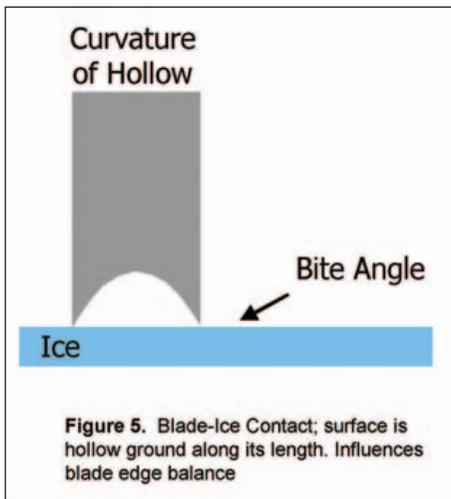


Figure 5. Blade-Ice Contact; surface is hollow ground along its length. Influences blade edge balance



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the hip is abducted, thus putting this muscle group under maximal strain. Dr. Eric Babins from the University of Calgary has reported a reduction in pain of the lumbar spine and lower extremity along with improved performance with proper fitting of skates, blade alignment and adjustment for leg length discrepancies as required due to the improved biomechanical balance above the skate blade.

step of biomechanical control, which is positioning the foot properly within the boot. A complete lower extremity and foot exam needs to be done as would be done for any athletic population, and a decision on foot orthotics can be made using sound Root



Figure 7: Skate Orthotic

The tight fit of skates can increase the incidence of Morton's neuroma and dorsal superficial compression neuropathies.

Clinical Biomechanical Balance

There are two steps in the process to assist a skater from a biomechanical perspective. The first is the positioning of the foot within the boot using standard podiatric biomechanical principles. The second is the balance of the blade onto the boot itself. Results from a recent pilot study (Baisch, Humble et al, 2013) suggest custom foot orthoses as designed below can assist figure skaters with postural control. This small study showed better stability of both the ankle joint and the knee joint by reducing internal-external rotation range, all the while increasing flexion-extension range of both ankle and knee joint.

Step 1: Foot Balance Within Boot—Custom Foot Orthotic

A general podiatric clinician can be confident when dealing with the first

biomechanical techniques.⁶ These techniques of forefoot to rearfoot and rearfoot to leg control will help to compensate for biomechanical faults, help stabilize the subtalar and midtarsal joints, and help maintain sound structural alignment of the lower extremity from the midtarsal joint to the hip, providing a solid lever for propulsion. This orthotic can then be improved upon by using a general understanding of skating mechanics and applying the newer techniques of foot orthotic control as discussed by Kirby and Blake.^{7,8}

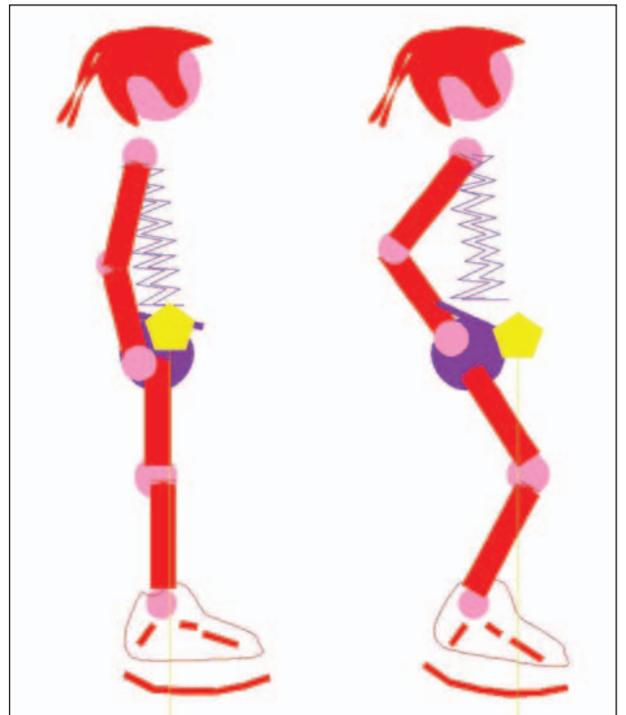


Figure 8: Sagittal plane rocker

As a skater is in single-limb support in the early stages of propulsion, the foot is abducted and the hip externally rotated. The skate and skater are moving in opposite directions at this time while trying to balance on the narrow skate blade. As such, the center of gravity is much more medial with respect to the weight-bearing extremity, and even subtle biomechanical faults, causing excessive foot pronation, will cause a skater to spend too much time on the medial skate edge. Power and efficiency are created by staying on



Figure 6: Haglund's deformity and counter expansion



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the outside edge as long as possible early in the typical skate cut. Therefore, maximally controlling the medial column of the foot with respect to the subtalar joint axis location can greatly assist a skater with this task. Using both the newer and traditional biomechanical controlling techniques improves skating power and balance during propulsion.

Orthotic Design for Skating (Figure 7)

- 1) Neutral suspension casts of feet.
- 2) Trace or send skate insoles with casts to improve boot fit.
- 3) Intrinsic forefoot posting unless custom added-depth skate boots are used.
- 4) Standardly, invert casts 10 degrees using Blake technique to increase medial arch contact and to increase

time spent on lateral blade edge. Increase as clinically justified.

5) Standardly, use a 3-4 mm medial heel skive cast modification to help with lateral edge control. Increase as clinically justified.

6) Polypropylene shells are preferable as they can be more easily modified as needed to the medial shank of the skate boot.

7) Extrinsic rearfoot posts work if well-skived to fit in the heel counter of boot and use a thin cap to decrease heel lift. There should be no motion allowed for in the rearfoot posting.

8) Use full-length extensions with thin top cover materials of good friction next to the foot for grip and "feel." A thin layer of firm Korex under the extension will decrease forefoot irritation

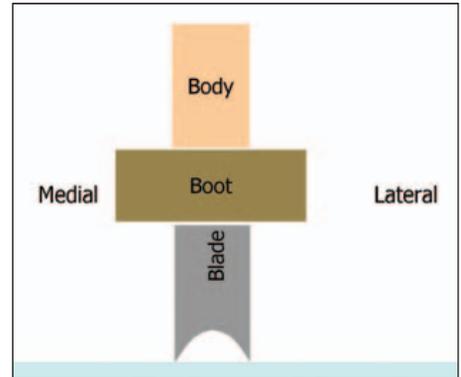


Figure 13: No wedge needed

from blade housing mounting rivets in the boot.

9) Some skaters like buttress or toe crest pads built into the extension for their toes to grip onto.

Balancing the blade with wedging is the final blade adjustment technique.

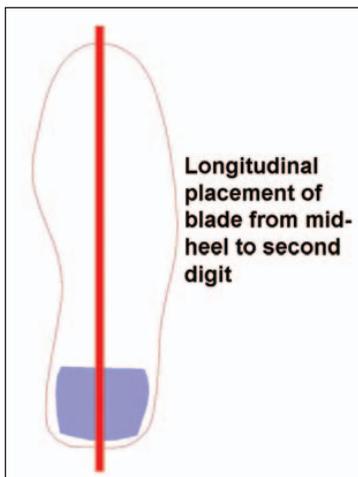


Figure 9: Standard blade placement

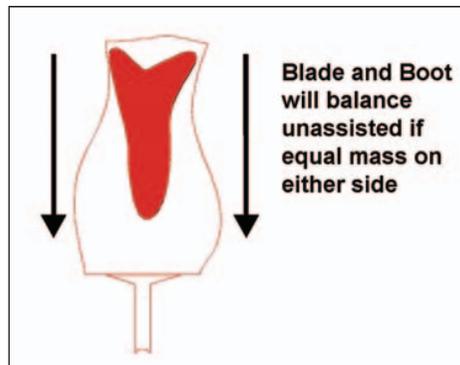


Figure 10: Standard blade placement, posterior view

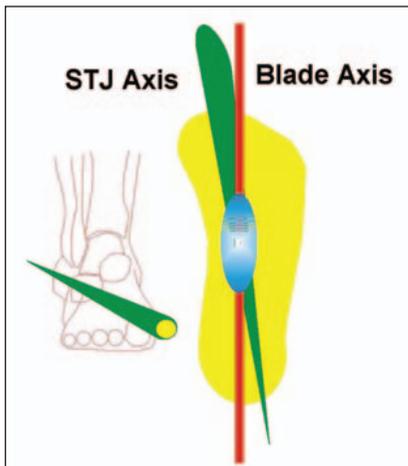


Figure 11: Standard blade placement compared to STJ axis

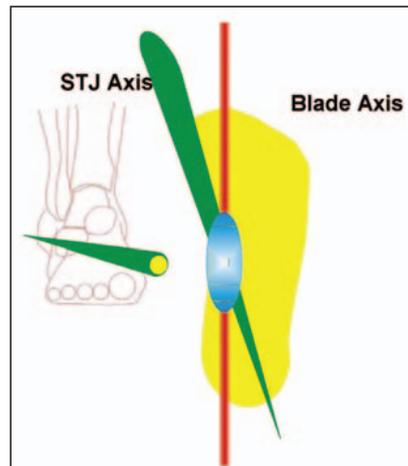


Figure 12: Shifting the blade medially will put it in a more functional position

Step 2: Blade Balance

The second step in mechanically helping skaters involves blade balance. Blade balance is accomplished using three different techniques: sagittal plane rocker, medial-lateral position of blade, and varus/valgus wedging of blade, which can incorporate limb lifts. These interventions are usually best performed by a professional skate mechanic after podiatric advice is given.

The sagittal plane rocker of the blade allows for easy response to the center of gravity changes in the sagittal plane. Standardly, the rocker is in the center of the blade with only one inch of the blade in contact with the ice. Some skaters will increase their rocker (decrease contact with ice) in order to improve their maneuverability. Others will decrease their rocker to allow more blade to contact the ice and this will increase speed but decrease turning capabilities. Adjustments of rockers are more a matter of individual preference for performance, and should only be done in the hands of a skilled skate technician (Figure 8).

The medial-lateral position of the blade on the boot has a significant effect on a skater's posture and balance. The standard blade placement is lon-

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gitudinally from heel center to the second metatarsal head, and second digit (Figures 9, 10). This blade position should provide an inherently stable platform for the foot to sit with pure sagittal plane rocking.

A medially deviated subtalar joint axis will influence the default contact portion of the standardly placed blade. Shifting the blade medially will place the default contact portion of the blade in a more functional position with respect to the medially deviated axis in those patients (Figures 11, 12). In extremely rigid inverted feet, moving the blade laterally on the boot will help to improve balance.

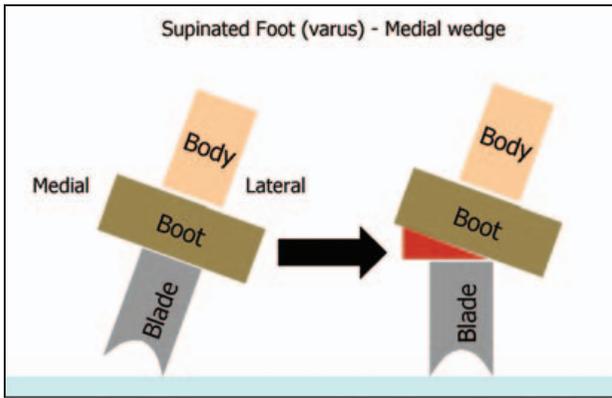


Figure 14: Supinated or lower extremity varum-medial wedge

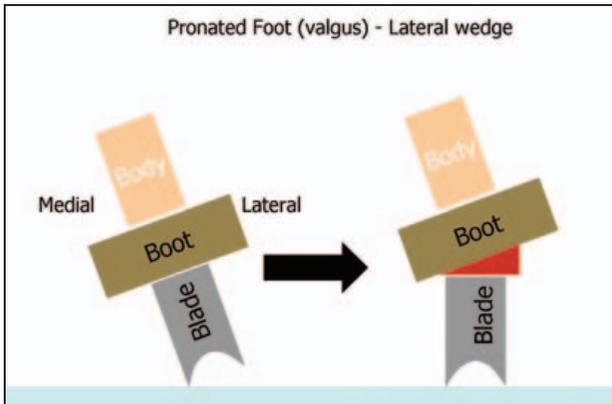


Figure 15: Pronated or lower extremity valgum-lateral wedge

Balancing the blade with wedging is the final blade adjustment technique. After an appropriate orthotic has been made, the rocker has been checked, the blade has been moved medially or laterally as needed, a decision on using a wedge can be made by looking at the position of the blade edges with respect to the weight-bearing surface. A wedge can assist in balancing the blade to the boot and upper body so that in static stance each edge of the blade balances on the ice surface equally. As odd as it may seem, a supinated or varus foot can require a medial wedge to bring the medial blade edge evenly to the ground. A pronated or valgus foot can require a lateral wedge to bring the lateral blade edge to the ground (Figures 13, 14, 15).

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The podiatric management of the skater can be best shown through a series of case examples. Each of these scenarios depicts the management of increasingly complex cases involving both foot-to-boot balance and blade-to-boot balancing techniques.

Case #1—Moderate Pronation

Ten-year-old white male suffers from medial arch and heel pain predominantly in his day-to-day activities, which carries over into his recreational hockey. He is otherwise fit and healthy and has been diagnosed with plantar fasciitis.

A complete podiatric biomechanical exam was performed and the pertinent results were a two-degree forefoot varus and a four-degree forefoot supinatus bilaterally (Figures 16, 17, 18).

The first goal in treatment was a daily orthotic to relieve his symptoms and the secondary goal was a skating-specific orthotic to improve his skating performance

posterior tibial tendon strain and patellofemoral pain syndrome was made. The primary etiology of his problems was deemed to be biomechanically produced from excessive foot pronation. He functions maximally pronated due to a fully compensated forefoot and rearfoot varus deformity bilat-



Figure 16: Case #1, Moderate pronation



Figure 17: Case #1, moderate pronation



Figure 18: Case #1, moderate pronation

Many blade adjustments were needed to assist in this patient's performance.

and his enjoyment of his recreation. The polypropylene skating orthotic was made from a neutral suspension cast with reduction of the supinatus. The casts were modified with 10 degrees of inversion and a 3 mm. medial heel skive. The forefoot was posted intrinsically 2° varus after the inversion cast modification, and a rearfoot post was added to balance the orthotic. A functional skate orthotic with maximal control was used to assist this patient, along with a good-quality and well-fitted skate boot. No blade adjustments were needed, and the blade was left in its standard default position.

Case #2—Moderate-Severe Pronation

Twelve-year-old male suffers from medial ankle and knee pain while playing hockey. He is otherwise fit and healthy. After a complete history and physical examination, a diagnosis of

erally of approximately four degrees for both (Figure 19).

A custom foot orthotic was manufactured from casts corrected to 25° of inversion using the Blake inversion technique and a 4 mm. medial heel skive was added. The forefoot to rearfoot was posted a further 4° of varus and a balancing post was placed on the rearfoot also in 4° of varus. A further mechanical intervention was needed and the blades were moved medially on the skates (Figures 20, 21, 22).

The final solution for this patient was a good quality skate boot appropriately fitted, an aggressive custom foot orthotic and a blade balancing adjustment.

Case #3—Supinated Pes Cavus Foot Type

An 18-year-old Western Canadian Hockey League player suffers from lateral leg and ankle pain, as well as skate

balance problems. History and physical exam finds him otherwise fit and healthy. A diagnosis of peroneal tendonitis was made due to a rigid forefoot valgus and a limb-length discrepancy (Figures 23, 24).

The mechanical solution to this patient's problem was a custom-made, added-depth skate boot to accommodate an orthotic with an extrinsic forefoot valgus post to the sulcus. Stan-

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Standard Root biomechanical principles were used to make this orthotic and no newer inversion techniques were utilized (Figure 25).

Many blade adjustments were

needed to assist in this patient's performance. A limb-lift was added full-length, the blades were moved laterally on the boots and a medial wedge was inserted to assist further in bringing the medial edge of the skate blade down to the ground (Figures 26, 27, 28).

Conclusion

Ice skating, and more specifically power skating, is showing increased popularity throughout North America. All podiatry practitioners can expect to see ice skaters in their-

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Figure 19: Case #2, Moderate-severe pronation



Figure 21: Case #2, blade adjustment



Figure 20: Case #2, skate orthotic

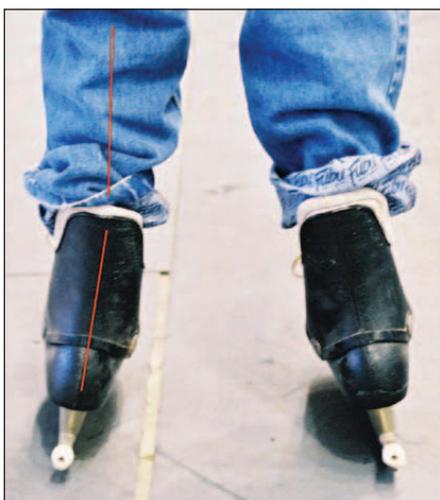


Figure 22: Case #2, end results



Figure 23: Case #3, forefoot valgus



Figure 24: Case #3, neutral cast



Figure 25: Case #3, skate orthotic



Figure 26: Case #3, heel lift

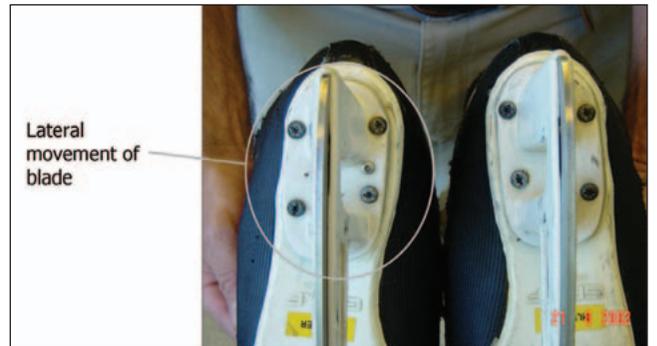


Figure 27: Case #3, blade placement

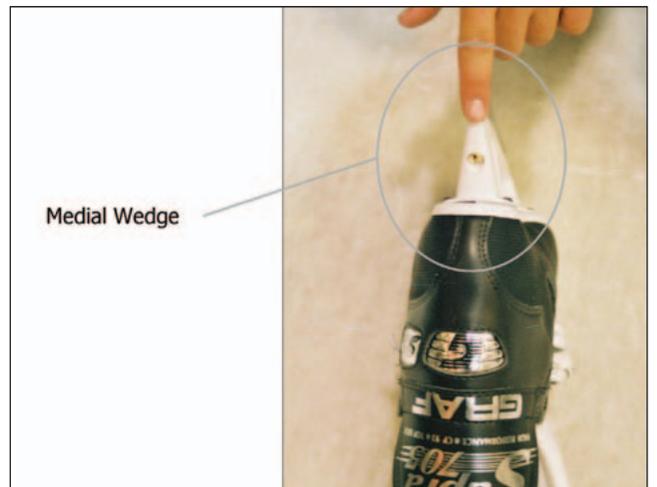


Figure 28: Case #3, medial wedge to balance

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All podiatric practitioners can expect to see ice skaters in their offices.

ical intervention can assist in the pleasure and performance of this unique activity. **PM**

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