Article 8

Boot Fitting Fundamentals

Boot Design

All ski boots are designed to provide a solid link to the ski allowing the skier to hold a carving edge. Boots designed with overlap construction are the equipment of choice for ski racers. Overlap boots are constructed with two components. The lower shell envelopes the foot and maximizes both support and sensation. The upper cuff attaches to the lower cuff and it transmits forces from the leg to the lower shell and ski. The attachment of upper to lower cuff should mimic the anatomic function of the ankle joint to support mobility. Boots that significantly restrict range of motion in the ankle inhibit performance. Some brands of boots provide adjustment features that allow the following:

- Forward lean adjustment
- Upper cuff *(lateral)* adjustment
- Heel lift adjustment
- Micro-adjustable buckles

Other adjustments include grinding and punching specific areas of the boot to accommodate individual differences in foot and lower leg shape. Stretching should be avoided unless *absolutely* necessary, due to the common side effect of distorting the alignment of the toe and heel lugs.

Grinding to modify the flex pattern of the boots *should only done by those who have experience* with the specific model of boot in question. Inappropriate grinding can destroy both the rebound and lateral stability of a race boot.

Alignment strategies include:

- Foot beds to provide a supportive foundation or *orthotics* to correct biomechanical problems
- Alignment of the upper cuff to the lower leg to enhance lateral balance, and allow to the skier to stand naturally on a flat ski.
- Alterations to the liner to provide a more even distribution of pressure, and individualize shell fit.

Due diligence should be exercised when providing foot beds to juveniles. Conservative advice is to do nothing, but there is little evidence to support the notion of causing permanent changes (either good or bad) to growing feet with the use of footbeds or orthotics. For this reason, athletes with "normal" feet can still benefit from an 'off-the-shelf' footbed to enhance comfort, fit, blood flow, balance, and decrease foot fatigue. Athletes with problem feet need functional sport-specific orthotics and should be evaluated by a sports medicine physician or podiatrist. Only licensed pedorthists, chiropodists, or podiatrists who are *familiar with the mechanics of skiing* should fabricate corrective orthotics.

Boot Selection

Boot manufacturers have different concepts of 'normal' foot shape and design their boots accordingly. Some brands have several different models and shapes. The most obvious, and measureable, differences are in the cuff, ankle, heel, instep, and toe box areas. The following are features that should be considered in the boot design for juveniles:

- Adequate boot length (try to avoid the 'racer' fit concept)
- Adequate room in the toe area - width and height
- Proper width for the forefoot
- Snug fit in the heel and the ankle area
- Suitable forward flex (athlete must be able to flex the boot in a tuck position at winter temperatures) and lateral stiffness

Boot Fitting Principles

- Know the technology of boot design and construction. Local ski shops can help you by allowing you to *try on* their inventory during quiet times.
- Look closely at the shape of the foot. Is the heel narrow or wide? Is the forefoot narrow or wide? Are there any anomalies in the feet and ankles that need to be accommodated? Do the toes lie flat?
- Consider stiffness of the boot. Juveniles are still growing and their bone and tendon structures are not yet fully developed. Be particularly aware of individuals who are big for their age. They are often not as strong as they appear; therefore it is better for the boots to have a softer forward flex for juveniles. The most important consideration is that the boot fits well, provides strong lateral support and allows the foot and the ankle to articulate properly.

Stiff boots reduce the range of motion in the ankle and force the skier to adjust by flexing other joints inappropriately - an outcome called compensation. The inability to blend and balance flex in the hips, knees, and especially ankles will inhibit the athlete's ability to remain in skeletal alignment which will ultimately cause early fatigue and increase the risk of injury. In addition, a lack of articulation in the ankle joints combined with excessive angulation will stress the knee joints as well. In summary, *boots that are too stiff disrupt mechanics, balance, relaxation, decrease performance, and increase the risk of both chronic and acute injury*. If the boots are too stiff, there can be no positive training effect!

The "jump" test is a simple procedure that can be used to help younger skiers select a ski boot that will enhance performance rather than hinder it. The skier should stand naturally in the boots with his/her hands of their hips. The skier flexes the ankle to prepare, and then jumps forward and up to land on the balls of the feet. Boots that are too stiff will limit the range of motion in the ankles; the skier will usually jump up and back. Correct boot fitting will allow the skier to bend the three joints of the lower body, the ankles, knees, and hips. The skier should be able to jump forward and up, landing on the ball of the foot and absorb the landing by bouncing or flexing with the ankles. Boots will always be stiffer in colder temperatures and this should be considered in selection and testing (if possible).

Boot Length

- Take liners out of the boots and place footbed (if athlete has one) in the empty shell.
- Place feet in the empty shells and slide feet forward until light contact is made between one toe and the front of the boot
- Flex forward and look at the gap behind the heel. You should be able to insert one finger in the gap and wiggle it. If it's a squeeze, the boot will fit too tightly. If you can fit two fingers it is too big.
- Remove feet from the boot and insert liner. Force the heels well back in the heel pockets. Stand up. It is not unusual to find liners much too tight while having the shell fit correctly. Modifying the liner is acceptable (heat & stretch *or* cut the toe box open - let the foot spread the liner open and tape it back up in its new position). This can be done at the end of the fitting session.

Boot Width

- Move the feet back to a central position in the shells. Does the forefoot area make contact with the sides of the shell?
- If the foot makes contact, the boot is narrow. If the foot makes contact on one side only, the shell should be ground out and/or punched on that side, or the liner can be trimmed to fit.

Boot Contours

- Assess the area around the ankles with bare feet in the shells. Does the shell contour match, or align with, the position of the ankle bones? If the difference is too great, try another brand of boots. If the difference is small, heat and punch the shell to match the ankles.

Cardinal Rules

- A boot that is too long in length will *never* fit properly
- Pressure points should be fixed immediately, especially in the heel area.

Cuff Alignment

Often mislabeled on boots as 'canting', cuff alignment is simply lateral adjustment of the upper cuff to match the shape of the lower leg. Cuff alignment does little or nothing to affect the position of the knee relative to the working edge. When the cuff is properly aligned, it allows the skier to stand on a flat ski. Compared to the lower leg shape, excess, or positive, cuff angle (cuffs 'out') causes a skier to stand on the inside edges and makes it difficult to initiate and release from carved turns. Insufficient, or negative, cuff angle (cuffs 'in') causes a skier to stand on the outside edges and makes it difficult to gain enough edge angle to create a platform and carve.

- Place the feet in the empty shells (with the footbeds in the boot) and place feet hip width apart. *Hip width means that the center of the foot (defined as a line passing through the second toe) lies under the center of the hip joint.* The gap on either side of the leg, at the top of the cuff, should be equal. If not, make necessary adjustments so that the gap is equal. This may require more adjustment than is

possible from any adjusting feature included with the boot. If so, *with the help of an experienced bootfitter,* remove the cuff and replace it in the proper position.

Canting

Cuff alignment is an adaptive adjustment whereas canting is a *corrective* adjustment. Orthotics influence the biomechanics of the foot and ankle, and canting influences the knee. The goal of canting is to bring the knee into better alignment in relation to the working edge by shimming the bindings or grinding the bootsole to the desired corrective angle. Many authors have suggested that the center of the knee should fall between zero and three degrees inside the midline of the boot. However, there are many successful athletes that fall outside this classical range. It is probably more relevant to assess athletes on hill to ensure that they are not grossly knock-kneed, bowlegged, or asymmetrical in their alignment. Canting adjustments should be done by an experienced bootfitter that can recognize pelvic misalignment and leg length differences. Boot selection, fitting, footbeds (or orthotics), and cuff alignment should be optimized *before* assessment of canting needs. Natural, symmetrical, relaxed carving skills are a good indication that canting is roughly accurate. Elite athletes often cant their boots to an accuracy of a quarter degree, but a discussion of that level of precision is beyond the scope of this article. Readers interested in a further exploration of this topic can refer to 'The Athletic Skier', by Warren Witherell & David Evrard.

Boot 'Verticalization'

Most race boots have a forward lean angle of 15-16 degrees, and a ramp (bootboard) angle of 6-8 degrees. The net ankle angle is forward lean minus ramp angle, which in most cases is around 9 degrees. This is why most people need to have at least 10-12 degrees of flexion range in the ankle (past 90 degrees) in order to ski in balance (see heel lift section that follows). In the majority of people, this range of flex in the ankle allows the knee to sit above the ball of the foot - an athletic 'ready position' common to many sports. If a boot is verticalized, the forward lean angle is reduced along with the resulting ankle angle. In most skiers, this can have a negative effect on balance and performance by transferring pressure to the heel, decreasing the ability to pressure the tongue of the boot effectively, and functionally reducing the role of the ankle joint. Nonetheless, there seems to be a persistent underground trend towards altering boots to make them more 'upright'. This does *not* include removing forward lean shims to create more room for people with large calves, regain range of motion, and encourage a natural skeletally aligned stance. Removing forward lean shims is often a good idea (except in those that have thin calves). There are few clear indications for testing verticalized boots, and the alterations are usually permanent. One group of people that *may* benefit from a more upright cuff are those that have a proportionately longer lower leg and shorter foot.

Boot Tuning

When you are satisfied with the fit, go skiing, readjust, and go skiing again. Repeat as necessary to get it right. Technical problems are often caused by poor foot mechanics, and/or poorly fit and aligned boots.

Heel Lift

Problem - boot looks too stiff, but when stationary, the athlete can flex it appropriately. When skiing, the athlete cannot get forward no matter how hard they try.

Possible solution - check for correct heel height. Many coaches and bootfitters will assume that the boot is the culprit and cut the upper and lower cuffs to soften it. Always assess heel lift needs first before making potentially unnecessary alterations to the boots.

The relationship and alignment of the calcaneus (heel bone), talus (small, saddle-shaped bone that sits between the tibia and calcaneus), and metatarsals (long bones of the foot) is critical. When the foot is not confined it can adjust to provide better balance. In the ski boot it can be held in misalignment, causing imbalance. *This is a controversial area among foot specialists, since many feel that an accurate assessment of bony alignment can only be done using both weight-bearing and non weight-bearing xrays of the feet.*

Most athletes require some degree of heel lift (look at most running shoes). Deciding on the appropriate amount of heel lift is an area of considerable misunderstanding - so, included below are 3 methods to help make an assessment.

One subjective way to calculate heel lift height is based largely on the athlete's ability to interpret and judge optimal pressure distribution. This generally requires a more skilled, intuitive, and experienced athlete.

Method 1: Select a thick, soft covered book, wide enough to allow both heels on it.

- With feet hip width apart (accurately, as already discussed), place both heels on an arbitrary number (thickness) of pages. The athlete is going to provide feedback while maintaining a relaxed stance.
- The athlete should focus on feeling the body weight evenly distributed between the heel and the ball of the foot. This may be different from one foot to the other.
- When the right thickness is 'felt', build a lift to match as an initial test.
- This can be built up from layers of 1/8" tempered hardboard, or hard durometer orthotic posting material, laminated together with contact cement. Grind to a tapered shape on a belt sander.
- Attach to the boot board and replace the liner.

Method 2: Sit the athlete on a low chair, upper legs parallel to the ground, ankles under knees (not behind or ahead), feet parallel.

- Have the athlete keep their heel on the floor and pull up the forefoot (flex the ankle) as much as they can, one foot at a time.
- Measure the distance to the floor from the ball of the foot, just behind the 5th toe
- 5 cm is a rough guideline for 'normal'
- Athletes with less than 5cm can try progressively larger heel lifts based on their range of motion (ie. 4cm - test a 5mm lift, 3cm - test 10mm, etc.)
- Athletes with small feet will have proportionately less range of motion

- Athletes with excessive range (far greater than 5cm) may sometimes require a *forefoot* lift, or a decrease in the ramp angle of the bootboard.

The last method has the potential advantage of being more objective, but requires some basic range of motion measurements to be made. Of course, introducing measurements and numerical guidelines appears more 'scientific' but is no more a guarantee of success than trial and error. Furthermore, the more measurements you make, the more you compound your potential for error! If in doubt, let the athlete, and your assessment of outcome (ski improvement) be the guide.

Method 3: Sit the athlete on table edge, feet and lower legs hanging relaxed, back of knees against table edge.

- Look at lower leg and foot from the side (one side at a time)
- Ask athlete to pull toes and forefoot up to the ceiling without flexing or extending the knee
- Estimate (if you have a good eye), or measure with a protractor (you know, the one you kept from high school for a useful moment like this!), the angle the foot makes with the lower leg. The lines you are using are the bottom surface of the foot and the line that runs from the center of the knee joint to the ankle joint. A minimum target is roughly 80 degrees.
- If you are uncertain about the athlete's effort, accuracy, or symmetry, have an assistant flex the foot up by pressing on the underside of the lateral (outside) surface of the foot.
- Athletes that can only actively and passively flex to 90 degrees can test a 1 cm heel lift
- Athletes that can actively and passively flex 80 degrees or more likely don't need a heel lift, but can test a small (several mm) one.
- Athletes that end up somewhere in between (around 85 degrees) can test a 5mm heel lift
- Construct heel lifts as in Method 1….

On the hill, use flat, even terrain. Rail the skis, allowing the side cut to determine an arc. A relaxed, centered position should be easily maintained. If the athlete can arc from turn to turn with fluid movement and balance, boot tuning is finished. If this benchmark is not reached, or if the athlete feels discomfort, test further lifts, both smaller and larger than the original. Sequence to appropriate size. Watch for discomfort in the heel area caused by the heel lift. If this occurs, grind the lift to fit.

Final Note

Minor adjustments to boots may be required during the season. It is important to act on acute problems with boot fit, alignment, and pressure points before they become chronic and ultimately inhibit skill development and performance.

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