THE EXTRA-AMBULATORY LIMB CONCEPT AS IT APPLIES TO THE BELOW-KNEE AMPUTEE SKIER

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INTRODUCTION

Although the avenues of recreation in the physical or athletic sense are often limited for the amputee, many have successfully been able to participate in snowskiing. For one of the authors, it was his experience as a skier, an amputee, and a prosthetist, as well as his need to “recreate” that accounted for the development of an extra-ambulatory prosthesis to be used specifically for snowskiing by the below-knee amputee skier. The extra-ambulatory limb, described in the following, enables the amputee to ski with maximum comfort and function, permitting him to ski at least as well as his conventional limb allows him to walk.

ALIGNMENT PRINCIPLES

It is important that the snow skier place his center of gravity ahead of the ball of the foot in order to ski well. This helps maintain balance, facilitates turning, and compensates for increase in speed. This is normally accomplished with ankle dorsiflexion or forward cant of 23 to 25 deg. Modern ski boots reflect this forward lean which is built into their design. A normal walking prosthesis can be modified for the correct amount of ankle flexion by placing a wedge under the heel of the boot on the ski. A small amount of forward cant can also be gained by wedging the heel inside the ski boot. However, one problem results with this modification. Due to the

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subsequent increase in socket flexion, the posterior brim of the socket is effectively raised in relationship to the patellar bar. When the amputee applies weight to the ski on his prosthetic side during a turn, his hip and knee on that side are in a good deal of flexion, more so than during any part of stance phase in normal gait. The result is an excessive and uncomfortable amount of pressure in the hamstring tendon to the popliteal area of the socket.

An effective solution to this problem is to move the socket forward of the foot in a linear fashion without significantly increasing socket flexion. Thus, with the socket flexed about 12 to 15 deg. and anterior to the foot so that the effective forward lean or ankle flexion is about 23 deg., the amputee is able to bear weight comfortably in the prosthesis with his center of gravity ahead of the ball of the foot (Fig. 1).

The most important biomechanical reason for moving the socket forward linearly without increasing socket flexion is that the skier is more effectively able to raise and lower his center of gravity. With a greater amount of initial socket flexion, any given amount of hip flexion will result in a correspondingly greater amount of anatomical knee flexion. The ability of the amputee to affect hip joint motion on his amputated side appears to increase greatly in positions of lesser anatomical knee flexion. One experienced skier was first fit...
with a limb in 35 deg. of initial socket flexion. Later the initial socket flexion was reduced to 15 deg. with all other variables of socket design and alignment remaining the same. His ability to ski improved immediately from the intermediate level to that of expert level. It appeared that he was much more able to control his total body position and particularly his hip joint motion through flexion to extension, so basic to the activity of skiing.

ALIGNMENT FOR THE PROSTHETIST

The alignment of the skiing prosthesis is easily accomplished. The prosthetist simply aligns the prosthesis for walking as he would with a conventional prosthesis. When this is done, the socket is moved forward in a linear fashion so that the anterior brim falls about an inch or so behind the toe of the foot. Finally, the overall length of the prosthesis is reduced so that it equals the sound side with ankle dorsiflexed at 23 to 25 deg. A SACH foot has been used quite successfully. There appears to be no need for an ankle joint in this prosthesis.

INTERFACE

Flexion and extension at the knee and hip are basic to the activity of skiing and create a rather unusual stump-socket interaction important in the consideration of interface material. The interface between the stump and socket should offer as much protection and cushioning as possible. The most effective interface for this purpose at this time appears to be the silicone gel insert. Each time the skier compresses or sinks at the hips he must decelerate this "down" motion to the point where it begins to be an "up" motion. This requires not only a contraction of the hip extensors but of the knee joint extensors so that the anterior aspect of the stump below the posterior brim comes in hard contact with the anterior aspect of the socket. Of course, a good deal of the anterior portion of the stump is composed of the tibia and its bony prominences that are essentially subcutaneous in the mature stump. Silicone gel offers a rather fatty tissue-like protection for the bony areas and has worked very well for the four skiers that have been fitted with prostheses for snowskiing.

SUSPENSION

If the amputee is to have any control of his prosthesis in skiing,
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Figure 2
Figure 3
Figure 4
Figure 5

PROSTHETIST

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there must be little or no piston action on axial movement of the stump in the socket. The less piston action, the less the reaction time between leg movement and the prosthesis on the ski. A wedge similar to the type used in a PTS prosthesis is located between the socket shell and the gel insert just proximal to the medial femoral condyle (Fig. 2 and 3). In addition to the wedge, a modified cuff of the type used in a PTS prosthesis is used. The medial and lateral tabs of the cuff are attached on the outside of the socket shell below the patellar-tendon level on the socket. Slots are cut into the socket on both the medial and lateral sides at the patellar-tendon level so that both tabs transfer from the outside to the inside of the socket shell (Fig. 4). The cuff fits snugly over the patella without any bridging of the tabs (Fig. 5). A waistbelt with an elastic “pick-up” strap that extends to the portion of the cuff just proximal to the patella is also used (Fig. 6). This helps eliminate piston action as well as reduce the effective weight of the prosthesis. The cuff is particularly useful while the skier rides the chairlift. The wedge not only aids in suspending the prosthesis but enhances the medial-lateral as well as rotational stability of the socket.

SUMMARY AND CONCLUSION

Three features of prosthetic design—alignment, interface, and suspension—have been presented in a new concept. Each is unique in that its design evolved from a consideration of snowskiing by the below-knee amputee. The result is a specialized prosthesis for use in an extra-ambulatory activity. It would seem that certain other physical activities could be so examined in order that prostheses suitable for different forms of recreation can be developed.

REFERENCES