Editorial

Beyond the Quadrilateral

by Hans Richard Lehneis, Ph.D., C.P.O.

Earlier this year I had the pleasure to be invited to the Academy Midwest Chapter Symposium entitled, "AK Design Principles: Beyond the Quadrilateral." I found the latter half of the title so intriguing and expressive of contemporary thinking and rethinking in AK socket prosthetics that I chose it as the title of this commentary. I hope that the organizers of the Chicago Symposium do not mind my borrowing this title.

One of the earliest and major break throughs in AK socket design in this century was the concept of ischial weight bearing. At first glance this appears to be a sound approach and certainly one that has improved general comfort over other sockets. If, however, one analyzes that concept more closely, i.e., biomechanically, it becomes clear that ischial weight bearing is not a reality through all phases of gait. It must be appreciated that the socket and, thus, the prosthesis as a whole during walking is controlled by movement emanating from the center of rotation of the residual hip joint. At heel strike, when the hip is flexed, the distance from the ischial tuberosity to the ischial seat of the socket increases with the angle of hip flexion (Figure 1). Obviously, at this point in the gait cycle, there cannot be any ischial weight bearing. Yet, the need to support weight is greater than at any other point during locomotion. Body weight, plus the force of impact must be transmitted. How is this possible without direct skeletal support?

I believe that, by what in German is called "verspannung" of the musculature, a stable interface is achieved. This is a phenomenon which every AK amputee must learn to prevent the prosthetic knee from buckling.

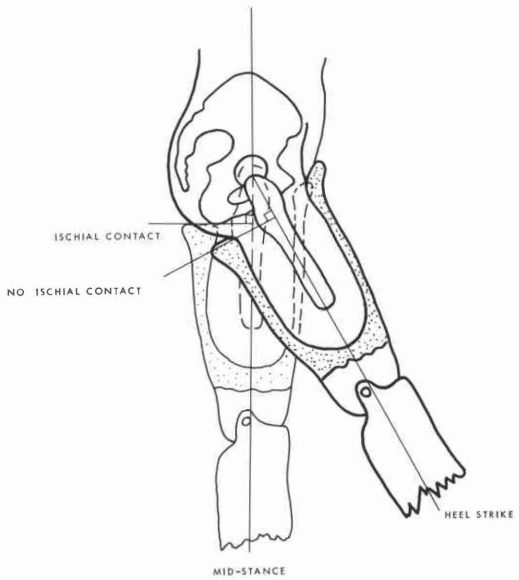

Figure 1.

Unlike normal locomotion in which there is phasic interaction of the musculature to produce controlled hip and knee flexion (eccentric contraction), the AK amputee must learn out-of-phase contraction of the hip musculature, i.e., the hip joint must produce an extension moment prior to heel strike so that the knee joint is in full extension at heel strike. Such muscular activity causes "verspannung," an increase in cross sectional volume, which in turn increases the tangential forces in the socket to equal the vertical forces generated at this point in the gait cycle.

While it is clear that reasonably comfortable ischial weight bearing is indeed possible in the midstance phase, ischial weight bearing cannot

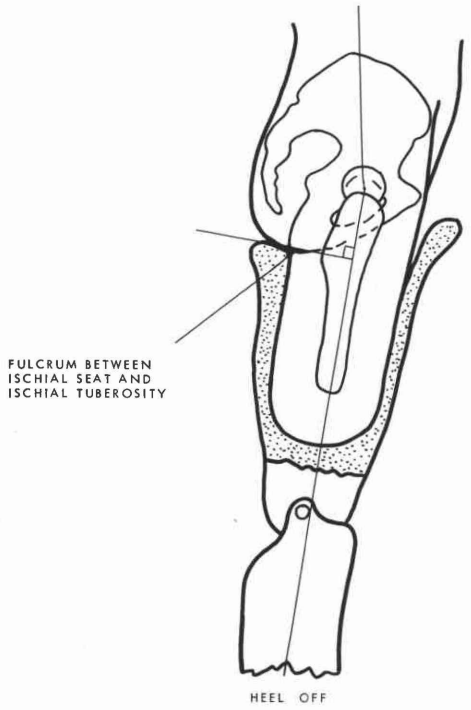

Figure 2.

be comfortably maintained at heel off. When the hip joint is extended, the perpendicular distance between the axis of rotation of the hip and the ischial seat of the socket is less than in the mid-stance phase (Figure 2), yet the distance from the hip joint to the ischium remains constant throughout all phases. Thus, hip extension causes increasing pressure on the ischial tuberosity, which now becomes the fulcrum about which the prosthesis tends to rotate. This results in the stump being pulled out of the socket, gapping of the anterior brim, elevation of the body on the involved side, and discomfort. Clinically, prosthetists have relieved this problem by increasing the radius of the anterior portion of the ischial seat. This maneuver allows the socket and seat to move posterior to the ischium as the hip is extended.

Personally, I have always advocated that the ischial seat is sloped forward and downward such that it is tangent to a radius from the hip joint to the ischium (Figure 3). This not only increases comfort at heel strike, since it reduces the sharpness of the anterior portion of the ischial seat, but at heel off, it allows the ischial tuberosity to be inside the socket and pressure

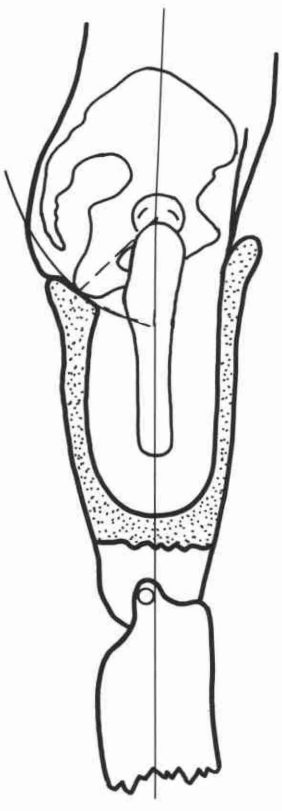

Figure 3a.

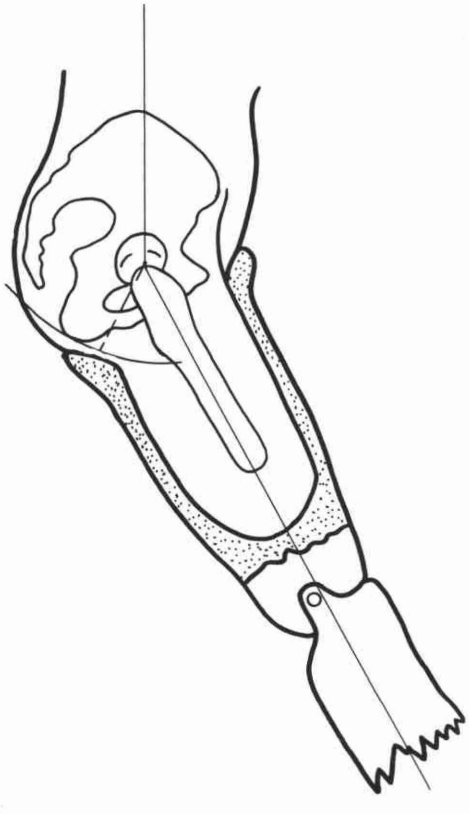

Figure 3b.

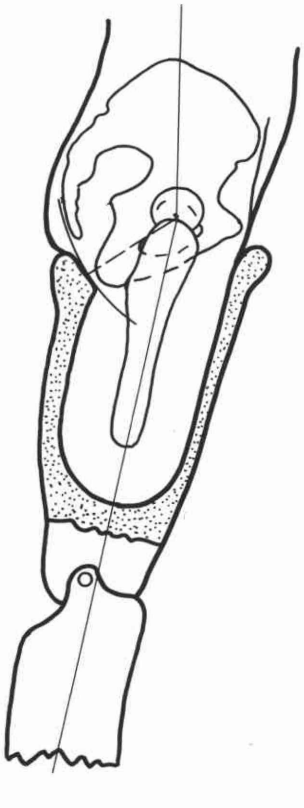

Figure 3c.

to be transferred to the much larger part of the ischium and gluteus maximus. Placing the ischial tuberosity on the anterior portion of the ischial seat also results in greater comfort, since it reduces skin tension in that area.

While one might argue that placing the ischial tuberosity squarely on the seat was a necessity with open-end sockets; it is amazing that this theory continued to persist past the advent of total contact sockets. Under certain conditions, Pascal's law may be applied to total contact sockets, i.e., a hydrostatic condition exists which would eliminate the need for ischial weight bearing. In other words, the quadrilateral shape of AK sockets has remained unchanged despite the fact that total contact has resulted in a different application of the laws of physics which makes ischial weight bearing less important than originally conceived.

Practitioners familiar with the fitting of prostheses to patients with Proximal Femoral Focal Deficiency (PFFD) know that the quadrilateral socket is inappropriate for these patients. A more appropriate socket shape resembles that of a flower pot in which the ischium is contained within the socket. In addition, the largest patient population for which the quadrilateral shape must be revised is the geriatric AK amputee. These patients, as a rule, become amputees due to Peripheral Vascular Disease (PVD), often compounded by diabetes. They usually present diminished sensation, reduced muscle tone, poor skin quality, and sometimes senility. Generally, they suffer from great discomfort when fitted with a prosthesis. Although most of this can be ascribed to the problems presented, it appears that some of this discomfort is due to the quadrilateral socket shape, particularly when the patient is provided with a manual knee lock. Unlike amputees who are fitted with an open knee and who must, and are able to, contract the residual muscles prior to heel strike, the geriatric amputee with a manual knee lock simply steps on the prosthesis. This simulates the effect of stepping on a rake (Figure 4). As a result, the tissue below the ischium is compressed (poor muscle tone), resulting in excessive skin tension, anterior proximal gapping of the socket, and the ischium to be far posterior to the socket.

In summary, it seems to me that in light of the change in patient population (overwhelmingly geriatrics) with all the physical problems they present, one should, indeed, think beyond the quadrilateral. One should also note that with the advent of total contact, the concept of ischial weight bearing needs to be re-visited and re-assessed. Designs such as CAT-CAM and work supported by the Veterans Administration at the Rusk Institute of Rehabilitation Medicine hold promise to go beyond the quadrilateral to improve patient comfort.

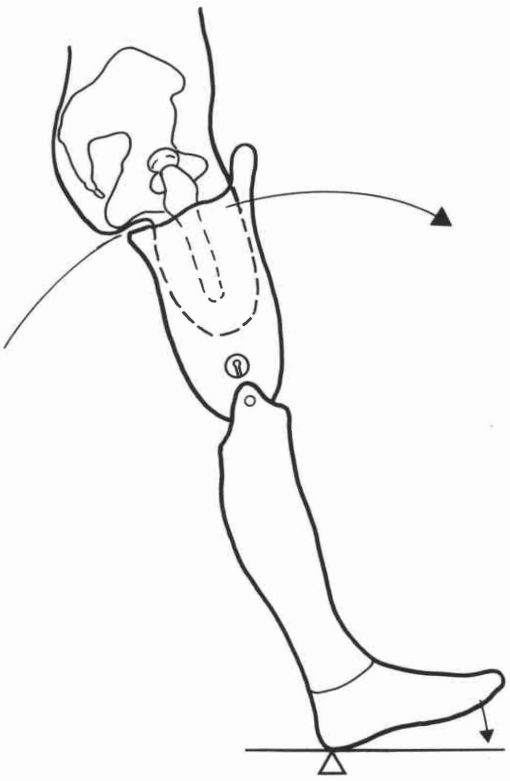

Figure 4.

ACKNOWLEDGMENTS

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