TIBIAL ROTATION

Gustav Rubin, M.D., F.A.C.S.
Consultant on Orthopedics

Veterans Administration Prosthetics Center
252 Seventh Avenue, New York, N.Y. 10001

INTRODUCTION

The rotation of the tibia and subtalar motion are being taken into account in some of the newer techniques for leg bracing. It is the purpose of this paper to investigate the precise relationship between these two movements.

The rotation of the tibia in a horizontal plane, occurring during stance, is rotatiön about a simple vertical axis to a limited degree only. The major range of tibial rotation is contributed by the subtalar joint which has a compound axis so directed as to produce tibial rotation as a primary movement.

It has been customary to view subtalar motion from the aspect of the various planes in which the foot moves during inversion-eversion, i.e., the frontal, sagittal, and horizontal planes. This, however, is essentially a non-functional concept. When the foot is on the ground, it would be more pertinent to be concerned with what happens to the segment proximal to the subtalar joint—the tibia.

During the stance phase, tibial rotation becomes dependent on the motion of the joints between the tibia and the floor. These are primarily:

1. The subtalar (peritalar) joint
2. The ankle joint
3. The mid-tarsal joint

The following describes a method for simulating the rotation of the tibia as it occurs in relation to these three joints.

THE SUBTALAR JOINT

A model of the subtalar joint was constructed with the axis (a simple hinge) placed in the position of approximately 41 deg. upward-anterior deviation from intersecting horizontal planes and 23 deg. medial-anterior deviation from intersecting sagittal planes. In its anatomical counterpart, this axis would pass from the dorsomedial aspect of the neck of the talus to the postero-inferior and lateral aspect of the os calcis in the region of the tuberosity. The resultant of this compound axis is an axis that closely approaches a vertical, permitting tibial rotation in a horizontal plane as the corollary of supination of the foot.

The model was placed alongside a normal extremity, and both the wood and the living models were provided with extended pointers (Fig. 1). Supination of the wood foot and concomitant supination of the living foot demonstrated the tibial rotation (Fig. 2). The extent of the rotation of the model "tibia" is such that 34 deg. of foot supination result in 58.5 deg. of "tibial" external rotation, that is, a 1 to 1.72 relationship (Fig. 3).

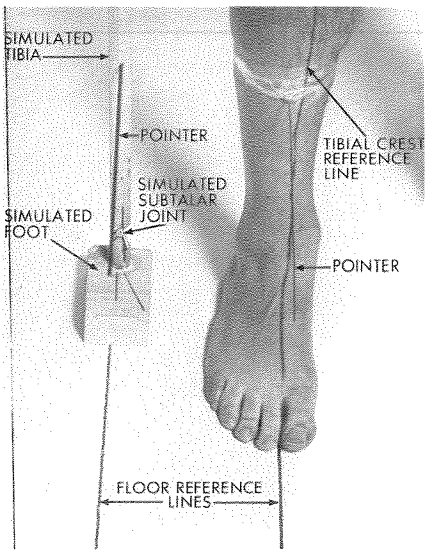


FIGURE 1.—Neutral position, model and foot. Note pointers.

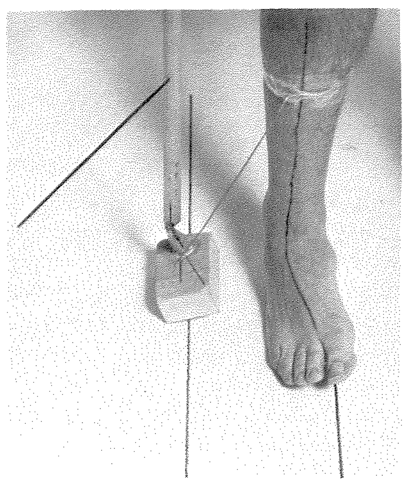


FIGURE 2.—Supination of both the model and the foot. Note the external rotation of the pointers.

In a previous paper the author demonstrated (2)[a] that supination of a model foot to 34 deg. (the range referred to by Steindler (3) as the average range of subtalar motion) produces, almost exclusively, tibial

[a] Several wood models were made based on information then available (1960) (2) for the joint axis, i.e., 16 deg. deviation from the sagittal plane and 42–45 deg. deviation from the horizontal plane (5,6,7). At that time it was concluded that the principal effect on the tibia of supination of the foot is tibial rotation. The wooden model technique has, incidentally, proven to be a useful device for illustrating subtalar motion (8,9).

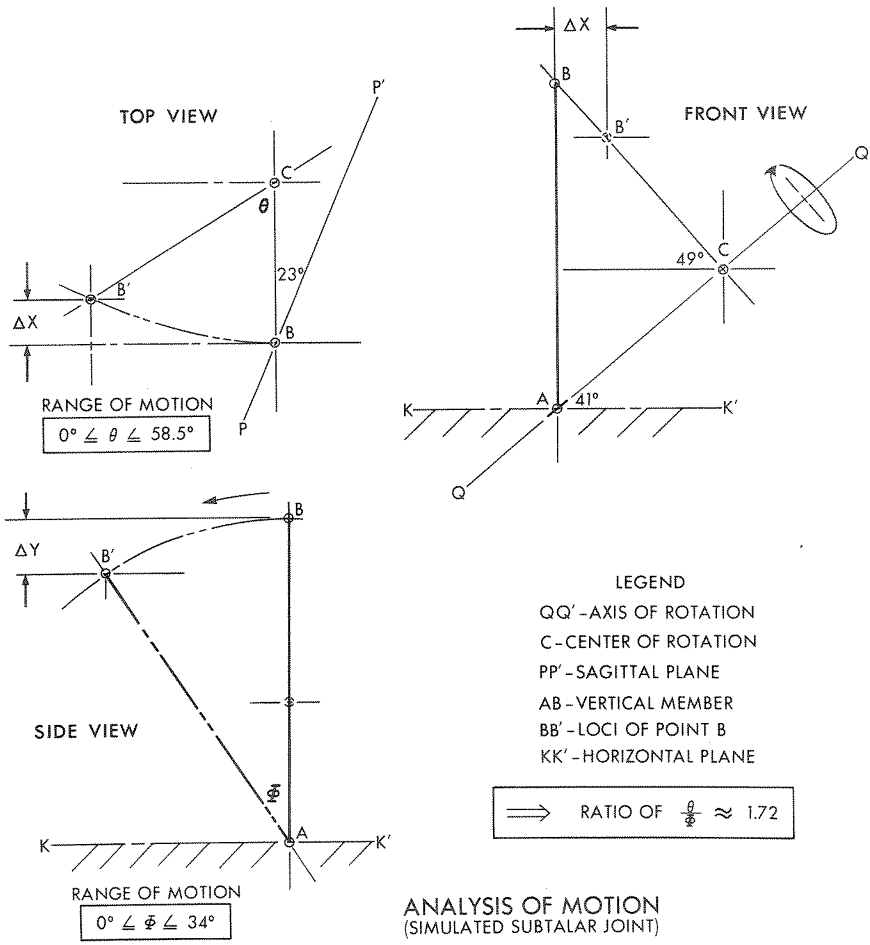
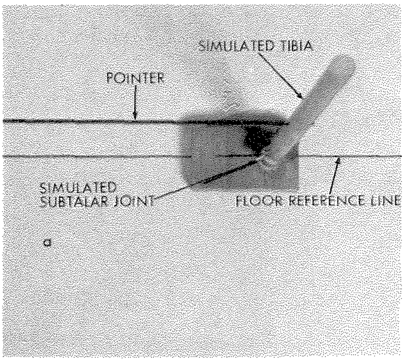
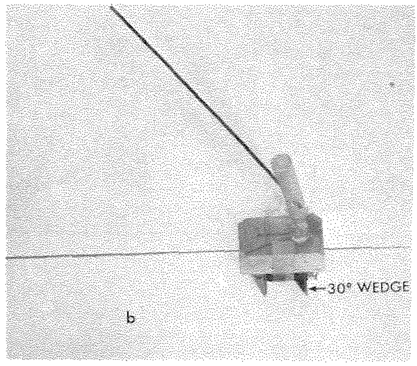


FIGURE 3.—Analysis of motion (simulated subtalar joint).

rotation (Fig. 4a, 4b, and 4c). This extent of subtalar motion is the extreme of that motion and is not to be construed as the range employed in normal locomotion. The average subtalar motion has been determined to be 6 deg. for a single subject during walking (4). In this single instance, on a 1 to 1.72 relationship, 10 deg. of tibial rotation would be anticipated. Horizontal tibial rotation about a vertical axis becomes even more important when the individual pivots laterally. With this movement the foot supinates and the tibia rotates externally, thereby allowing the pivoting motion to occur.





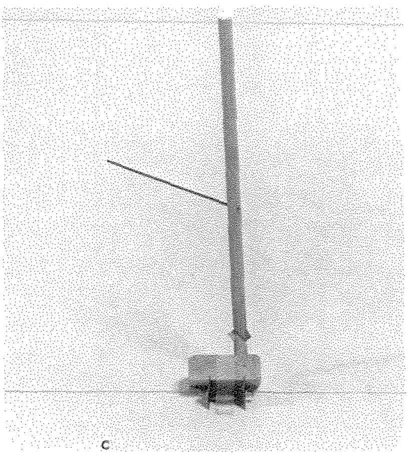


FIGURE 4.—a. View of model from above, b. external "tibial" rotation of 58.5 deg. has occurred; the foot has been supinated 34 deg., c. lateral view of "b." There is a slight "tibial" flexion; therefore, the motion produced by supination is almost entirely "tibial" rotation.

THE ANKLE JOINT

Isman and Inman (1) determined that the mean axis of the ankle joint formed an angle of 10 deg. with the long axis of the tibia. This served as the basis for a model constructed to evaluate rotation at this joint (Fig. 5). Anatomically, the trochlea of the talus is cone-shaped (10) with the apex of the cone 4–5 in. medial to the ankle joint, and the anticipated rotation would be true rotation about a vertical axis passing through this apex.

If all other influences are eliminated and the joint structure alone is considered, then, when the tibia is flexed on the ankle joint (or the foot is dorsiflexed) internal rotation of the tibia occurs (Fig. 6); and, when the tibia is extended on the ankle joint (or the foot is plantarflexed) external rotation of the tibia is noted (10).

It has been observed that this expected rotation is, in the normal foot, counteracted by torque (8,10). Therefore, although there is a mechanical basis for rotation at this joint, it does not, in fact, occur.

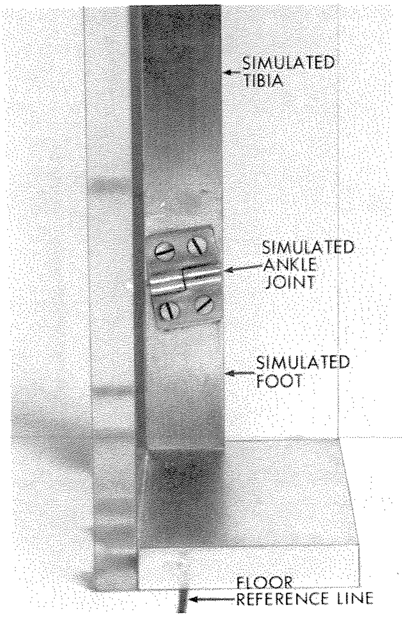


FIGURE 5.—Ankle joint axis of 10 deg. has been built into model.

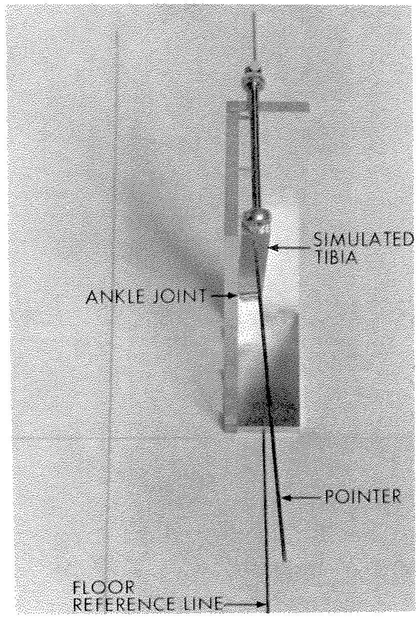


FIGURE 6.—The "tibia" has been flexed 20 deg. Note the internal rotation as indicated by the pointer.

MID-TARSAL JOINT

Figure 7 shows internal rotation of the leg with the foot firmly fixed on the ground. In the illustrated example, the full extent of rotation has been forcefully obtained. This extreme situation is likely to arise

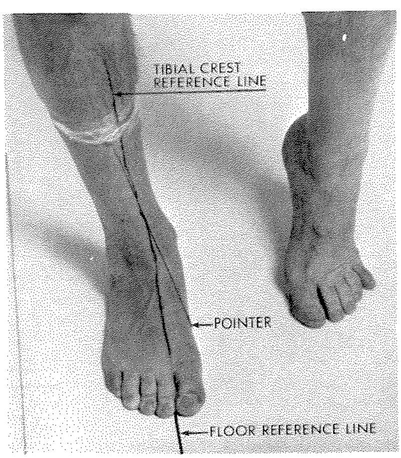


FIGURE 7.—The subject has pivoted medially with the foot on the ground (the neutral position is illustrated in Fig. 1). Note the internal rotation. In this single instance the range is 10. deg. This will vary with mid-tarsal mobility.

when the subject pivots medially. When this does occur the subject can not only sense the medial movement of the head of the talus, but he can also sense a lateral movement of the os calcis in its thick, compartmented, fatty sheath. The tibial rotation that occurs is simple rotation about the long axis of the tibia.

CONCLUSIONS

The theoretical rotation contributed to the tibia by the ankle joint, and anticipated by its anatomical construction and the direction of its axis, is counteracted by torque (8, 10).

The internal rotation secondary to mid-tarsal joint motion becomes most significant when the individual pivots medially on the foot. During lateral pivoting, subtalar motion occurs. As the subject pivots laterally and supination of the foot occurs, the concomitant tibial rotation in a horizontal plane becomes an important adjunct contributing to the ease of this motion.

The principal source of tibial rotation is the subtalar joint. Because of the direction of its axis this joint would not appear to permit true rotation about a simple vertical axis at all. Nevertheless, since this is a compound axis in the direction described, the movement translated to the tibia is almost pure rotation.

Rotation of the tibia is taken into account in the design of the VAPC single-bar rotation brace (11). For the rotation brace to take advantage

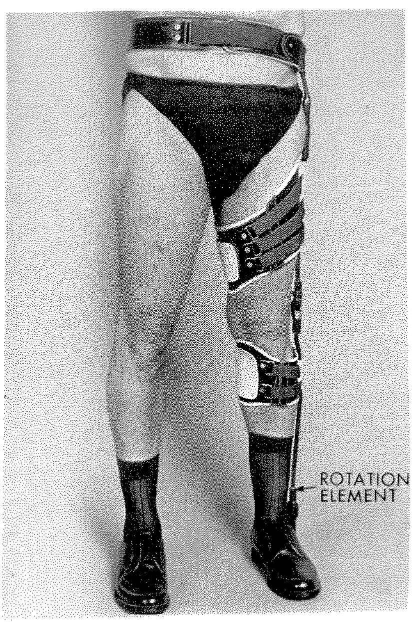


FIGURE 8.—The VAPC Rotation Brace.

of all sources[b] of tibial rotation, subtalar motion within the shoe must be permitted. Since the average range of such motion is 6 deg. (4), the mobility within the shoe need be quite limited. This brace is unique since it allows rotation and, nevertheless, in the presence of weak peroneal muscles, stabilizes the lateral ankle sufficiently to prevent turning over (12) (Fig. 8).

ACKNOWLEDGMENT

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REFERENCES

1. Isman, R. E. and V. T. Inman: Anthropometric Studies of the Human Foot and Ankle. Bull. of Prosthetics Res. BPR 10-11:92-129, Spring 1969.
2. Rubin, G. and M. Witten: The Talar-Tilt Angle and the Fibular Collateral Ligaments. J. Bone & Joint Surg., 42-A(2):311-326, Mar. 1960.
3. Steindler, Arthur: The Mechanics of Normal and Pathological Locomotion in Man. Charles C Thomas, Springfield, Illinois, 1935.
4. Wright, D. G., S. M. Desai and W. H. Henderson: Action of the Subtalar and Ankle Joint Complex During the Stance Phase of Walking. Biomechanics Laboratory, University of California, San Francisco, Berkeley, Number 48, June 1962.
5. Hicks, J. H.: The Mechanics of the Foot. I. The Joints. J. Anat., 87:345-357, 1953.
6. Close, J. R. and V. T. Inman: The Action of the Subtalar Joint. National Research Council Advisory Committee on Artificial Limbs, University of California, College of Engineering, Berkeley Prosthetics Devices Research Project, Series II, Issue 24, 1953.
7. Manter, J. T.: Movements of the Subtalar and Transverse Tarsal Joints. Anat. Rec., 8:397-410, 1941.
8. Inman, V. T.: The Influence of the Foot-Ankle Complex on the Proximal Skeletal Structures. Artificial Limbs, 13(1):59-65, Spring 1969.
9. Inman, V. T.: UC-BL Dual-Axis Ankle-Control System and UC-BL Shoe Insert. Bull. of Prosthetics Res., BPR 10-11:130-145, Spring 1969.
10. Close, J. R. and V. T. Inman: The Action of the Ankle Joint. Prosthetic Devices Research Project, Series II, Issue 22, April 1952.
11. McIlmurray, William and Werner Greenbaum: Draft Manual. Single-Bar Leg and Leg-Thigh Braces. VA Prosthetics Center, New York, N.Y., Sept. 15, 1970.
12. Rubin, Gustav and Morris Witten: The Unstable Ankle. The Bull. of the Hospital for Joint Diseases, XXV (2) :179-190, Oct. 1964.
13. Levens, A. S., V. T. Inman and J. A. Blosser: Transverse Rotation of the Segments of the Lower Extremity in Locomotion. J. Bone & Joint Surg., 30-A(4):859-872, Oct. 1948. Quotations from pp. 869 and 871.

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[b] Levens et al., determined that in the stance phase, "The magnitude of the relative rotation is approximately 7 deg. inward, during the interval from 7 percent to 17 percent of the walking cycle, and it is approximately 8 deg. outward from 17 percent to 43 percent of the walking cycle" (13).