Orthotics and Prosthetics, Vol. 30, No. 4, pp. 43–46, December 1976

THE EFFECTS OF HEEL HEIGHT AND ANKLE-FOOT-ORTHOSIS CONFIGURATION ON WEIGHT LINE LOCATION: A DEMONSTRATION OF PRINCIPLES[1]

Thomas M. Cook, M.S.[2]
Barbara Cozzens, B.S.[2]

The purpose of most lower-limb orthoses and prostheses is to impose or control sets of forces on the body to provide stability, mobility, and deformity prevention (*3*). A review of current literature in the field discloses numerous comments about the lower-limb "weight line" along with proposed guidelines regarding its proper location for optimal alignment. Although there are many "rules of thumb" for the ideal weight line location, the origins of many of these rules are unclear (*1*) and their applicability to various pathological conditions has yet to be subjected to scientific scrutiny.

From a theoretical point of view, to maintain a stable upright standing posture, the torques, or moments, about the supporting joints must be in equilibrium, i.e., the forces in the muscles and ligaments multiplied by the perpendicular distances to each joint center must be equal and opposite to the supported weight multiplied by the perpendicular distance between the weight line and the joint center. The counteracting muscle force requirements can be altered by increasing or decreasing the magnitude of the weight borne on that limb (at the cost of affecting the other limb or an assistive device) or by changing the distance from the weight line to the joint axis, or by a combination of both. The second approach, namely, controlling the weight line location, is the goal in most applications of ankle-foot orthoses (AFO's).

As recently stated by Stills (*4*), the two factors that control the weight line location in AFO applications are: 1) the position of the foot part of the orthosis with respect to the shank part of the orthosis; and 2) heel height. The purpose of this paper is to use actual weight line measurements to examine the interrelationship of these two factors.

MATERIALS AND TECHNIQUE

The measurement technique used an optical beam splitter[3] to superimpose the weight line on the lens of a camera used to photograph the subject (Fig. 1). The subject, in this case, a normal 25-year-old female, stood on a strain gage type of force plate that provided signals necessary to display on a large television monitor a vertical line that represented the weight line. The horizontal location of the line represented the vertical projection of the resultant force, that is, the weight line, on the platform with an accuracy of less than ± 0.5 centimeters. Appropriate signal conditioners and an analogue circuit calculated the force line location. (This technique can be used to assess medial-lateral alignment in either leg as well as the total body "weight line.")

The subject wore three different molded polypropylene ankle-foot orthoses (Fig. 2) (*3*) with each of three shoes with a different heel-height. The foot-shank angles of the orthoses were 75 deg., 90 deg., and 105 deg. and the sole-to-heel height differences were 0.9, 2.5, and 5.7 centimeters.

[1]This work was supported in part by Grant Number 23P-55518 from the Rehabilitation Services Administration, Department of Health, Education and Welfare.

[2]Rehabilitation Engineering Center, Moss Rehabilitation Hospital, Temple University, 12th Street & Tabor Road, Philadelphia, Penn. 19141

[3]Edmund Scientific Co., Barrington, N.J.

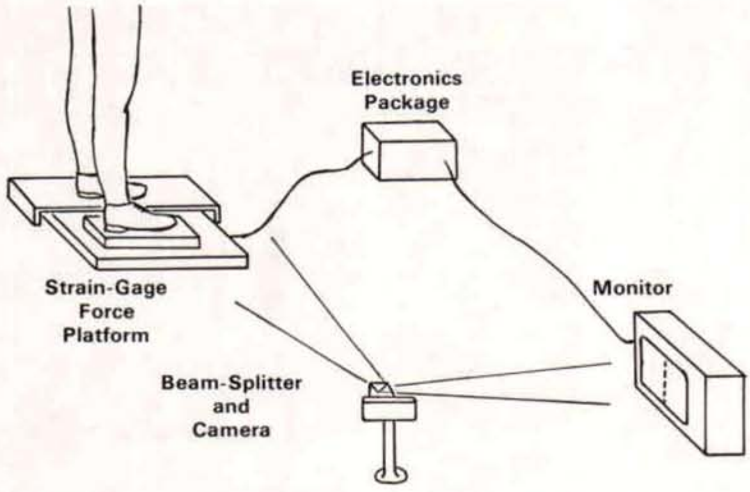

Fig. 1. Schematic of the equipment used to superimpose weight-line on photograph of a subject at rest.

Fig. 2. Molded polypropylene ankle-foot orthosis used in the demonstration. Left, AFO with ankle portion in dorsiflexion; Center, AFO with ankle portion in neutral position; Right, AFO with ankle portion in plantar flexion.

FINDINGS

Figure 3 shows the position of the weight line when the subject stands without shoes in a relaxed condition on the force platform. This line represents only the location of the weight borne on the right leg. The left leg is supported by an over-platform which is not in contact with the force plate.

Figure 4 shows the force line locations with the various heel-orthosis combinations. Column

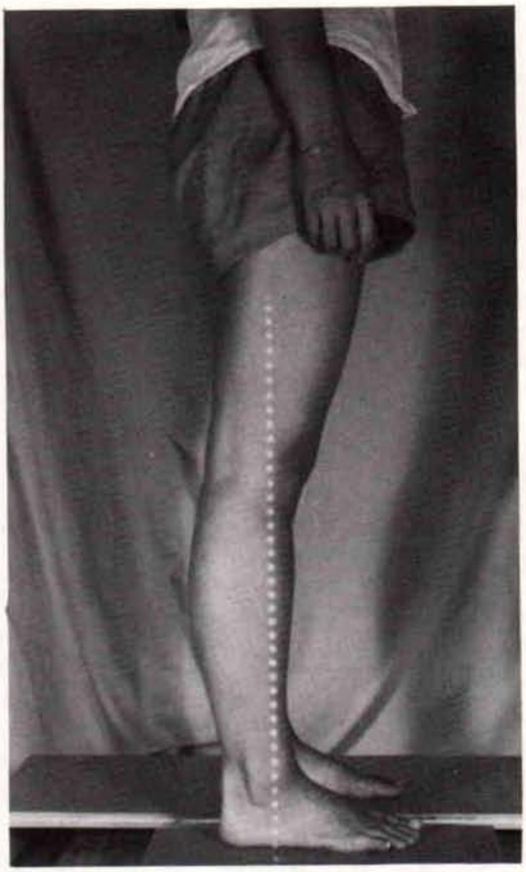

Fig. 3. Weight-line superimposed on photograph of subject standing without shoes.

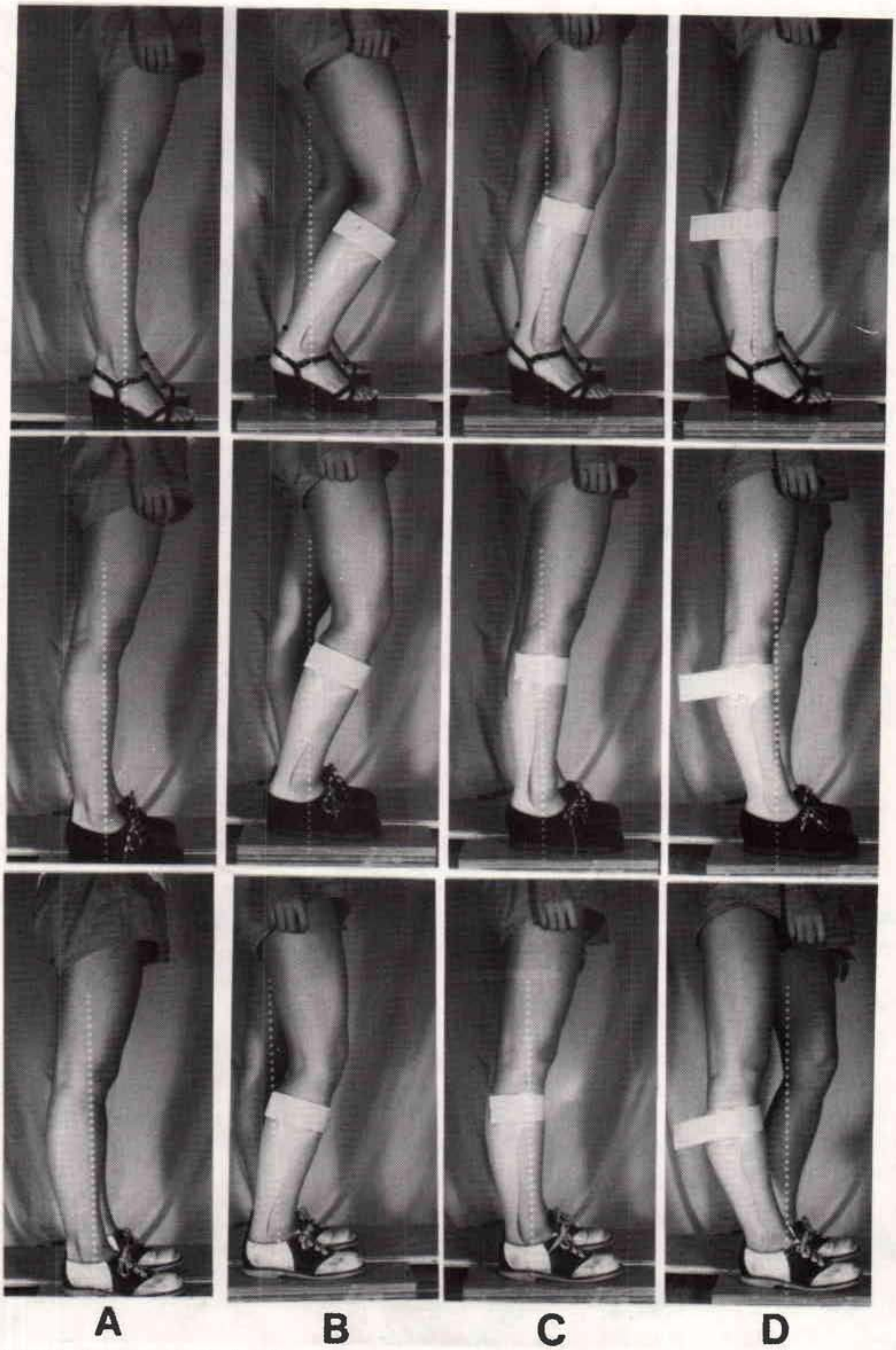

Fig. 4. Matrix of photographs showing effects of heel height and orthosis configuration on the patient in a standing position.

A shows the weight line with various heel heights prior to any orthotic application, and it can be seen that the weight line relationships at the ankle, knee, and hip appear unaffected by heel height. This is in agreement with previous findings by Hellebrandt (*4*).

In column B the subject is wearing the AFO with 15 deg. of dorsiflexion. In all instances the weight line is anterior to the ankle and posterior to the knee producing a knee flexion moment. The highest heel height causes the subject to stand with the left as well as right knee flexed.

In column C, the AFO having a 90 deg. shank-foot ankle relationship and the lowest heel height results in an alignment apparently identical to the non-braced condition. Higher heels again shift the force line posterior to the knee.

In column D, the AFO with 15 deg. of plantar flexion has been applied and the highest heel height seems to result in optimal alignment while the lower heels shift the force line anterior to the knee causing an extension moment. It should be noted that the location of the weight line under the foot seems to be affected very little except in the extreme cases of heel-orthosis combination.

DISCUSSION

Although the findings on only one subject are presented here, several other normal subjects have been examined also with substantially identical results. The principal implication from these pictures is that heel height and AFO configuration must be closely matched if optimal biomechanical alignment is to be effected. Both orthotist and patient must be highly cognizant of the fact that a particular orthosis requires an exacting match-up of heel height. The increasing use of thermoformed orthoses which fit inside standard street shoes will increase the likelihood that patients may use shoes with heel heights different from that for which the orthosis was specifically designed. This tendency is probably greatest among younger patients who are more style conscious.

The technique presented here seems to offer considerable potential for examining a wide range of orthotic and prosthetic devices, at least from the viewpoint of static alignment, and a number of such investigations are currently being undertaken. How static alignment relates to the dynamic activity of locomotion is a more crucial and complex question for the biomedical scientist (*3*).

The practitioner will ask how such a procedure, with its elaborate electronic and photographic features, could be implemented in the clinical setting. Work is currently being done at the Krusen Research Center, Moss Rehabilitation Hospital to develop a simpler device for clinical use. It is our aim to provide a practical device that will enable the clinician to apply more precisely general principles, such as those demonstrated above, to individual patients in order to provide maximal stability, mobility, and deformity prevention.

LITERATURE CITED

1. Brunnstrom, Signe, *Center of gravity line in relation to ankle joint in erect standing*. Phy. Ther. Rev. 34: 3:109–15, 1954

2. Hellebrandt, F. A., et. al., *The base of support in stance: its characteristics* and the influence of shoes on the center of weight. Physiotherapy Rev. 17:6, 1937

3. McLaurin, Colin A., *Trends in research,* In: Atlas of Orthotics, p. 485, C. V. Mosby, 1975.

4. Stills, Melvin, *Thermoformed ankle-foot orthoses*. Orth. and Pros. 29:4:41–51, December 1975.