

A NEW METHOD FOR ASSESSMENT OF THE STATIC AND DYNAMIC WEIGHT-BEARING OF THE FOOT

(Preliminary Report)

By

H. WETZENSTEIN

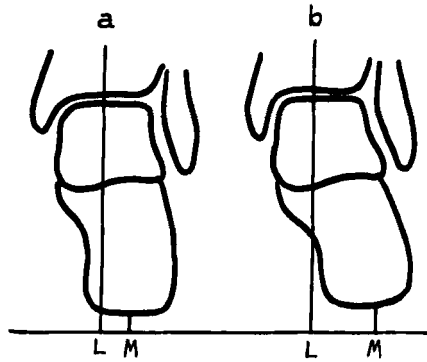
In judging the weight-bearing of the foot, the examiner is limited chiefly to the findings on inspection, which give him a rather subjective impression of the nature and severity of the possible abnormality. This uncertainty is especially evident when comparing the findings at different times. Subjective assessments of this kind can hardly be used in a scientific investigation.

With even less certainty can the examiner form an opinion of the weight-bearing when the foot is hidden in a shoe. It is therefore difficult to judge objectively the value of, for example, arch-supports and similar corrective measures.

The several measuring methods which have been published are concerned with an objective registering of the load on the foot. (Abramson, Carlet, Eberhart and Inman, Holden and Muncey, Schwartz and Heath, and others). These methods are partly very complicated and partly unsuitable for a special study of the weight-bearing in shoes.

The author has therefore developed a new method for the qualitative and quantitative measurement of the foot's weight-bearing in shoes.

The basis for this method is the load as it spreads itself out over the weight-bearing surfaces of the foot. The point of resolution of the weight-bearing load which corresponds to the point of action of the load on the weight-bearing surface, migrates over the foot, during a step, from the heel to the forefoot. The purpose of the study is to determine if the movements of the weight-bearing load are sufficiently significant to allow a delineation of different types of weight-bearing.

*Fig. 1.*

Schematic sketch of the medial deviation of the load with valgus weight-bearing (b).
 L = Load, M = middle-point of the heel.

*Fig. 2.*

The measuring instrument built into the heel of the shoe. The heel cap is partly cut away to show the position of the instrument.

Fig. 1 shows schematically the medial deviation of the load with, for example, valgus weight-bearing.

In collaboration with Arne Söderholm, engineer from the Royal Institute of Technology in Stockholm, a measuring plate has been con-

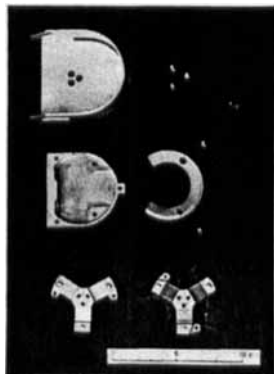


Fig. 3.

The dismantled instrument. At the bottom, the cantilever construction; on the left before, and on the right after gluing on the strain-gauges.

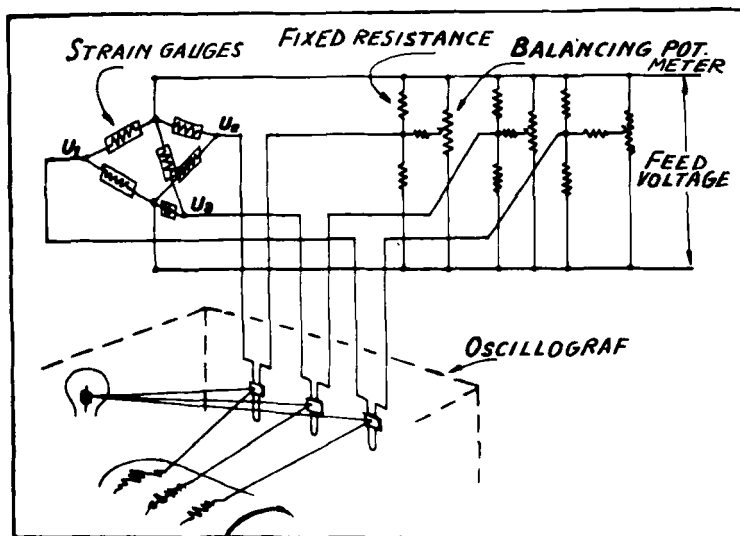


Fig. 4.

Circuit diagram of the measuring instrument, zero balance device and oscillograph (mirror galvanometers).

structed which registers the vertical load through the heel region. The plate is countersunk in the heel of the shoe. (Fig. 2).

The measuring apparatus is made of a stiff spring-balance, consisting of a plate which is carried by three cantilevers. On each cantilever are mounted two strain-gauges, one on the upper side and one on the lower side. (Fig. 3).

The cantilevers have a certain flexibility, and it is this deflection during loading by force which influences the strain-gauges. The resistance-changing produced in them are directly recorded by means of mirror galvanometers (Visicorder).

Fig. 4 gives schematically the electrical circuits.

With the help of the three curves which are obtained, the total vertical load (P) is calculated, and also the point of action of the load (by means of α and β) according to the formulae:

$$P = \frac{K}{E} (U_1 + U_2 + U_3)$$

$$\alpha = \frac{U_1 - \frac{1}{2} (U_2 + U_3)}{U_1 + U_2 + U_3} \cdot L$$

$$\beta = \frac{\frac{\sqrt{3}}{2} (U_2 - U_3)}{U_1 + U_2 + U_3} \cdot L$$

Where,

K = Calibration factor. E = Supply voltage. U = Tracing of the curves in mm.
 L = Measuring Constant (in this case amounting to 22).

α , β and P are calculated for every load phase over the heel at 9 points spaced at equal times over the curves. (Fig. 5).

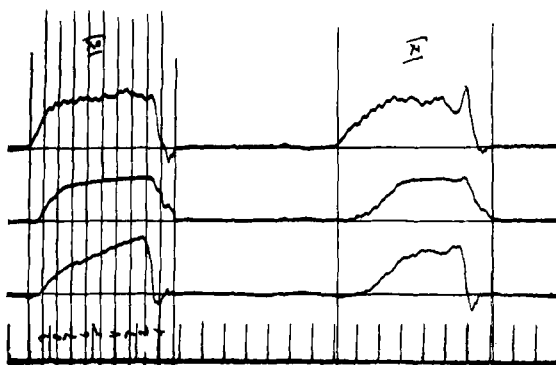


Fig. 5.

An example of the curves from the oscillograph (Viciocord), with the tracings (U_1 , U_2 , U_3) from two phases of weight-bearing. The short vertical marks at the bottom of the figure denote tenths of a second.

α represents transference of the load from the Y-axis in the anterior-posterior direction, and β from the X-axis in the lateral or medial direction. (Fig. 6).

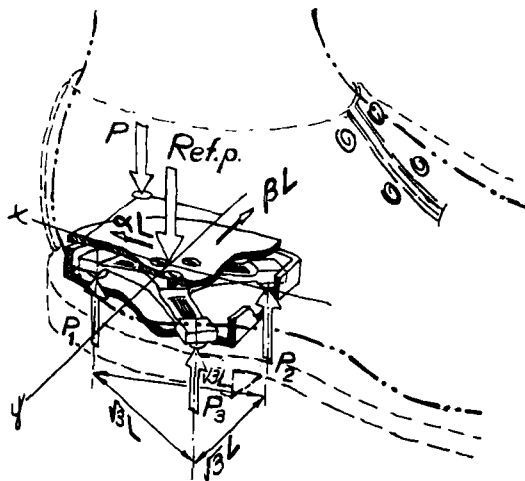


Fig. 6.

Schematic sketch of the measuring instrument in the heel of the shoe with the Y and X-axis indrawn.

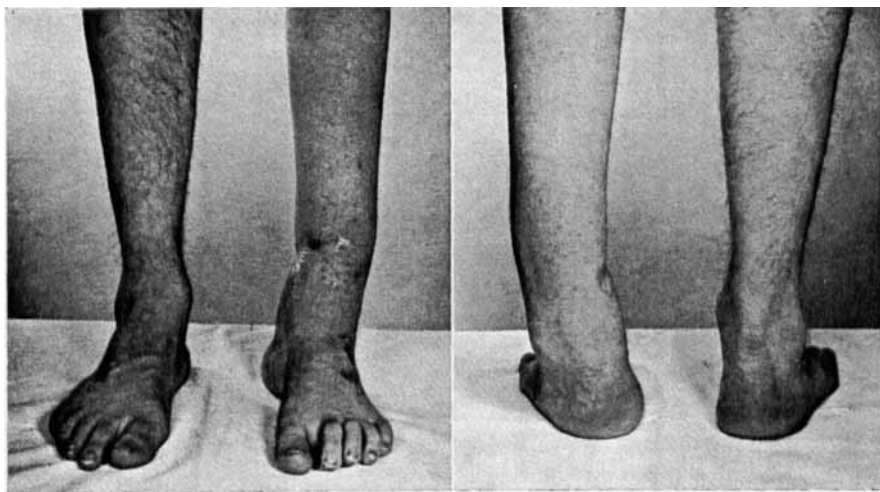


Fig. 7.

Patient with pseudarthrosis of the left tibia with varus weight-bearing.

By summation of the α and β tracings, one obtains a resolution which corresponds to the point of action of the load. Throughout the weight-bearing on the heel during a step, that is from the first setting down of the heel until the load, is a characteristic migration of this point of action from the back to the front of the heel region. This migration can

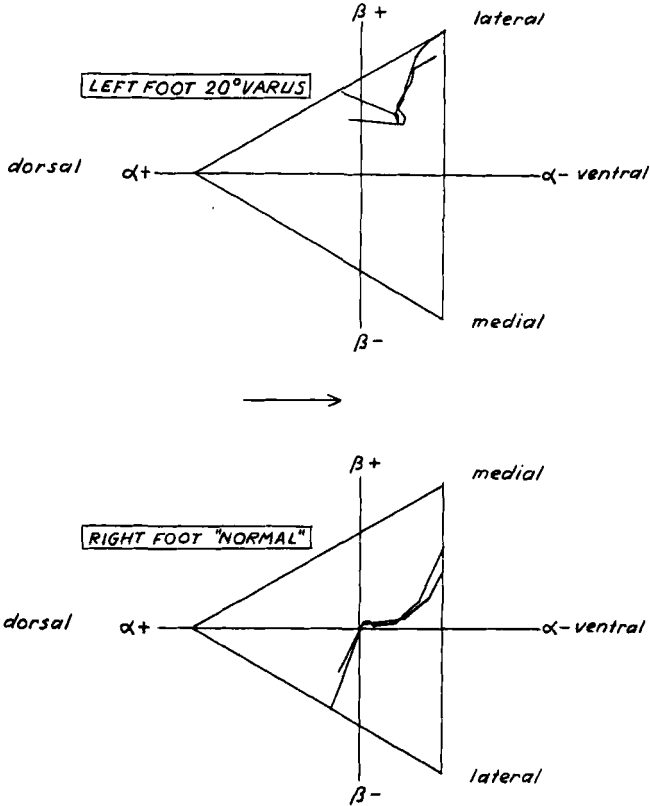


Fig. 8.

The diagram shows the varus weight-bearing on the left foot with the points of action of the load falling laterally.

be set in relation to the total vertical load (P), and to the lapse of time which can be read off in tenths of a second.

After calibration of the sensitivity of the instrument, trial measurements were performed on a number of experimental subjects with various degrees and types of abnormal weight-bearing and also some with no apparent abnormalities according to clinical assessment. The measurement examinations were performed on standing and walking, the latter on a treadmill.

To illustrate the possibilities of the method, the result obtained on examination of a patient with an obvious varus position of the left foot (over 20°) is shown. (Fig. 7). Varus weight-bearing resulted from a pseudarthrosis of the tibia immediately above the ankle joint. The right foot was clinically normal.

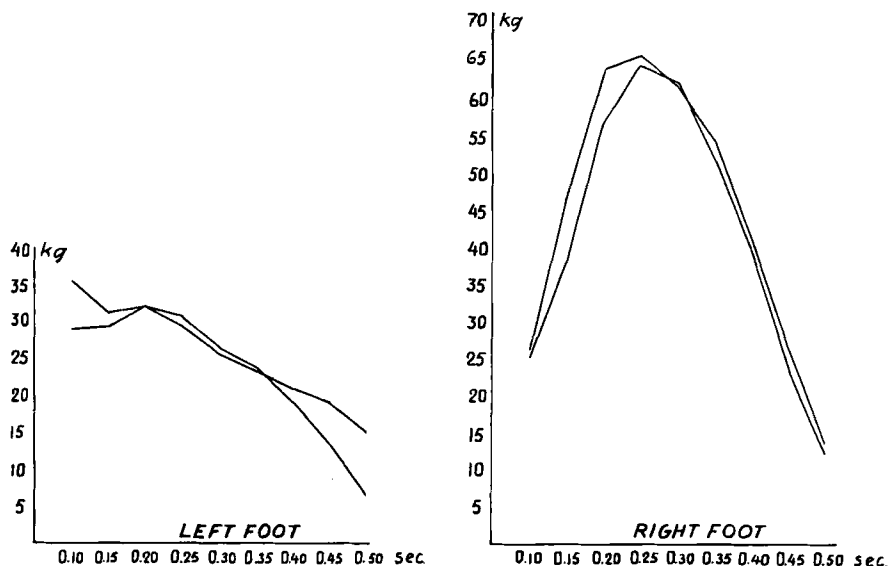


Fig. 9.

Diagram of the total vertical load in Kilograms for the steps shown in Fig. 8.
The patient's weight 73.4 Kilograms.

The diagram (Fig. 8) shows the triangular-shaped calibration areas on the measuring plates for the left and the right heel. The line which runs from dorsal to ventral ($+\alpha$ to $-\alpha$) corresponds to the x-axis, and the line from lateral to medial ($+\beta$ to $-\beta$) to the Y-axis. The arrow represents the direction of walking. With the help of the α and β values the resolution points of the load have been inserted and connected so that they are represented by lines. Two different steps have been recorded and each line in the diagram represents one step. As expected the varus foot's weight-bearing points fall laterally. The normal foot's weight-bearing migrates from laterally to medially. This measurement was done with the patient walking at a speed of 4 kilometers per hour on a treadmill. The step frequency was 116 per minute. The weight-bearing on the heel lasted from about 5 to 7 tenths of a second.

In the following diagram (Fig. 9) the magnitude of the load with regard to the vertical component only, is shown for the same step in Kilograms. It is clearly shown that the heel of the varus foot bears less weight. This agrees with the obvious clinical limp.

To illustrate the differences between varus and valgus weight-bearing as it appears in the curves, a diagram is now shown in which the β -values from four examination subjects are assembled for comparison.

(Fig. 10). The β -curves show to what extent the load fell medial or lateral to the measuring-plates' middle line (X-axis). In the diagram only the left foot of each subject was recorded and two steps are represented. The degrees of valgus or varus weight-bearing have been estimated by clinical examination and are approximate. The curves show clearly the obvious fact that varus feet take more weight on the lateral side and valgus feet take more weight on the medial side.

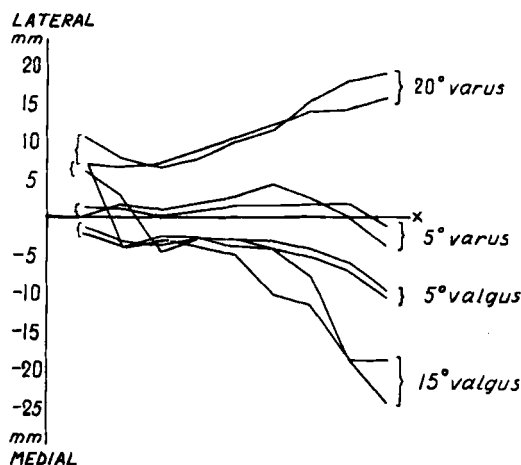


Fig. 10.

Diagram illustrating the differences between varus and valgus weight-bearing on the left foot of four subjects.

SUMMARY

A new method has been developed for recording the dynamic and static weight-bearing of the foot in a shoe. The vertical component of the load is measured in the heel region. For this purpose a stiff spring-balance is used in which the deflection is registered by strain-gauges.

The resolution of the weight-bearing load which corresponds to the point of action of the load on the weight-bearing surface, migrates over this surface in a characteristic way during the weight-bearing phase of a step. Whether this migration is sufficiently significant to allow a demarcation of different weight-bearing types will be investigated during the continuation of the work.

It is also possible to make similar measurements even under the fore part of the foot's weight-bearing surface.

The purpose is to get a technically simple measuring apparatus for

objective registration of the foot's weight-bearing on standing and walking in shoes.

RESUME

Une nouvelle méthode a été conçue pour enregistrer le poids dynamique et statique porté par le pied dans le soulier. Le composant vertical de la charge est mesuré dans la région du talon. A cet usage on utilise un balancier flexible raide dans lequel la déflexion est enregistrée par strain-gauges. La résolution de la charge du poids porté, qui correspond au point d'action de la charge sur la surface portante, oscille sur cette surface d'une manière caractéristique pendant la phase qui s'écoule pour faire un pas.

On étudiera dans des travaux ultérieurs si cette oscillation a une signification suffisante pour permettre une démarcation des différents types de poids porté.

Il est aussi possible d'effectuer des mesures similaires sous la partie antérieure de la surface du pied portant le poids.

Le but est d'arriver à construire un appareil de mesure très simple pouvant enregistrer objectivement le poids supporté par le pied dans le soulier, pendant l'arrêt ou la marche.

ZUSAMMENFASSUNG

Eine neue Methode zur Messung der dynamischen und statischen Belastung des Fusses im Schuh ist entwickelt worden. Die vertikale Komponente der Belastung wird im Bereich der Ferse gemessen. Zu diesem Zwecke verwendet man eine steife Federwage, in welcher die Federung mittels Dehnungsmesstreifen registriert wird.

Die Resultante des Belastungsdruckes, die dem Angriffspunkt der Belastung auf der Unterlage entspricht, wandert während der Belastungsphase eines Schrittes in charakteristischer Weise über die Belastungsfläche. Ob diese Wanderung hinreichend signifikant ist, um eine Abgrenzung von verschiedenen Belastungsformen zu erlauben, wird in einer folgenden Arbeit untersucht werden.

Es besteht die Möglichkeit, entsprechende Messungen auch unter den vorderen Stützpunkten des Fusses vorzunehmen.

Die Absicht ist, einen technisch einfachen Apparat zur objektiven Messung der Belastung des Fusses beim Gehen und Stehen im Schuh zu erhalten.

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