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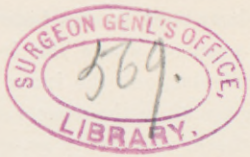

THE MECHANICS AND TREATMENT OF THE BROKEN-DOWN FOOT.*

By ROBERT W. LOVETT, M. D.,
BOSTON.

This paper deals with the theoretical and practical aspects of a position of the foot which will be designated as "pronation," a name perhaps correct, perhaps incorrect, but arbitrarily assumed for purposes of discussion to designate a certain factor in connection with flat-foot and other affections of the arch of the foot.

By pronation I mean the combination of some degree of eversion of the sole with abduction of the forward part of the foot; the weight-bearing position of the foot as distinguished from the position of the foot at rest.

The attempt has been made to make an application of old and well-known principles, and to call your attention to points in the mechanics of the breaking-down foot which have been overlooked somewhat in the task of studying the mechanics of the foot already broken down.

The position of the foot at rest, the non-pronated foot,

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is assumed to be that where the line of the crest of the tibia, prolonged downward, passes between the second and third toes; the position where the inner border of the toe, the inner malleolus, and the inner surface of the condyle of the femur are all in the same vertical plane. These standards are, I think, universally accepted as correct for the foot bearing little or no weight. If weight is borne on the leg more and more until the whole body weight comes to the ground through one foot, a certain movement takes place which up to a certain point is normal, and beyond that point pathological. This movement is of the nature spoken of as "pronation," and is made manifest most obviously by an inward prominence of the internal malleolus. This symptom in severe cases is the one most often noted in growing children, while adults often are troubled by wearing out their boots on the inner side of the sole, and by noticing that they walk and stand too much on the inner border of the foot. The condition is sometimes spoken of as "weak ankles"; most often the milder grades of abnormity are wholly overlooked.

Excessive pronation—that is, abduction of the forward part of the foot, plus dropping inward of the inner malleolus (eversion of the sole)—is a necessary anatomical accompaniment of flat-foot; that is, of breaking down of the arch of the foot. Excessive pronation of the foot also accompanies contracted foot, which Dr. Shaffer speaks of as non-deforming clubfoot; and excessive pronation of the foot is a condition existing without any heretofore recognized change in the arch of the foot. This condition I venture to speak of as pronated foot, meaning really abnormally pronated foot, but abbreviating the term for practical purposes.

Believing that this pronation of the foot varies more in proportion to the amount of pain suffered in flat-foot, con-

tracted foot, and the foot with no change in the arch, than any other factor, I beg to call it to your attention as worthy of study.

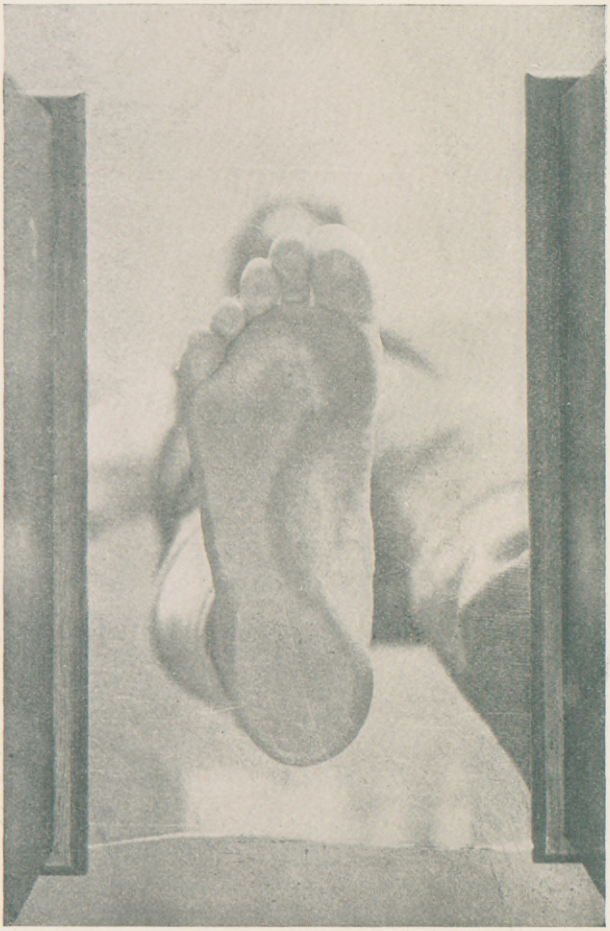

FIG. 1.—Photograph of the foot imprint in the "normal" position bearing little weight. (Through glass.)

The smoked tracing of the foot, or the imprint tracing of the foot made by any means, is unreliable for purposes

FIG. 2.—Photograph of the foot imprint in the weight-bearing or pronated position. Contrasted with Fig. 1, this shows that the weight-bearing surface has moved inward, and that the arch has narrowed. In this model the amount of pronation was not abnormal.

of study, as I learned long ago from clinical experience, and lately it came in my way to find the reason for this. I am indebted to Dr. H. J. Hall, formerly house surgeon at the Children's Hospital, for the method used, which was devised by him for the study of certain conditions existing in Pott's disease. The patient stands on a piece of plate glass supported between two tables, and the surgeon, looking up through, sees the line of contact of the foot with the glass as a dead white area where the pressure is greatest, and as a less anæmic area where the pressure is less. There is no difficulty in distinguishing the line of contact of the foot with the glass. With a crayon the observer draws on the lower side of the glass the outline of the foot in any position he chooses, with weight and without weight, and he notes the points of pressure. The patient steps off of the glass and a piece of moderately thin paper is then placed over the glass and a lamp or candle under it, by means of which the crayon outline can be seen through the paper, and so can be drawn on the paper for permanent record.

FIG. 3.—Tracing of the foot taken through glass. The black outline is the normal and the broken line is the pronated position. The amount of pronation in this case was approximately normal.

Tracings made in this way demonstrate plainly enough that there is one tracing for the foot in the normal position and another for the weight-bearing or pronated foot, and that the ordinary imprint tracing is a composite of the two,

and I wish to demonstrate to you tracings and photographs of the weight-bearing foot by itself; for in imprint tracings made in any other way the non-weight bearing tracing is indelibly recorded before the weight-bearing tracing can possibly be reached. The study of almost any smoked tracing will demonstrate this to you, for in it you will find two tracings laid over each other, heavier in the middle where they overlap, darker on the edges. It is possible that the study of the foot by this method may throw light upon some of the obscure problems connected with so-called "flat-foot," especially in its lighter grades.

In the foot held in the position described as normal, whether or not it is bearing weight, the chief points of pressure can be seen as white areas under the heel and beneath the third metatarsal. The arch bears, as a rule, some weight, but less than one would suppose, decidedly less than the heel and the distal ends of the metatarsals. The weight is plainly borne on the outer side of the foot. This is with the feet beside each other, neither one advanced, and with the model standing naturally, leaning neither forward nor backward.

If, now, the foot is pronated and the inner malleolus rolls in, the whole weight-bearing surface of the foot is seen to change and to move inward; the point of pressure under the heel varies but little, but the point of greatest pressure in front is likely to move inward until it is under the great toe in cases with much yielding. The behavior of the arch is curious and unexpected. It does not broaden often; it generally remains of about the same width as in the foot in the normal position, but simply moves inward; often it becomes narrower in the pronated foot, and in the pronated position it may be wholly lifted from the ground.

So much for the glass tracings. Next, as to the analysis of the movement by composite photographs. These

pictures were made by a double exposure on a slow plate, one exposure for the normal and one for the pronated position.

Pronation as a movement has the following clinical features:

The toes remain practically stationary, while the whole leg rotates inward at the hip. Studied locally at the ankle, the features are these: The inner malleolus moves inward, downward, and backward; the outer malleolus forward, but not downward or upward; the whole foot rolls over somewhat to the inner side.*

That is, the whole movement consists in a rotation of the leg with regard to the toes, which are comparatively stationary. This affords a means of measuring the amount of pronation, a most desirable matter for its accurate study, especially as the smoked tracing is worthless.

In the normal foot in the non-weight-bearing position —that is, when the inner border of the toe, the inner malleolus, and the inner condyle of the femur are in the same vertical plane—the following equilateral triangle may be constructed: A line is drawn from a point in the cleft between the third and fourth toes to the middle of the internal malleolus. This line in the normal foot should be exactly equal in length to a line drawn from the same point between the third and fourth toes to a point at the posterior quarter of the external malleolus. The measuring can be done with an ordinary tape measure between points marked with the ordinary fountain pen.

If now the foot is pronated, the inner malleolus moves backward, the outer malleolus forward, while the point between the toes is comparatively stationary, and in the weight-bearing position the line to the inner malleolus is

* Cf. Golebiewski. Studien über die Ausdehnungsfähigkeit des menschlichen Fusses. *Zeitsch. für orth. Chir.*, Bd. iii, S. 2 and 3.

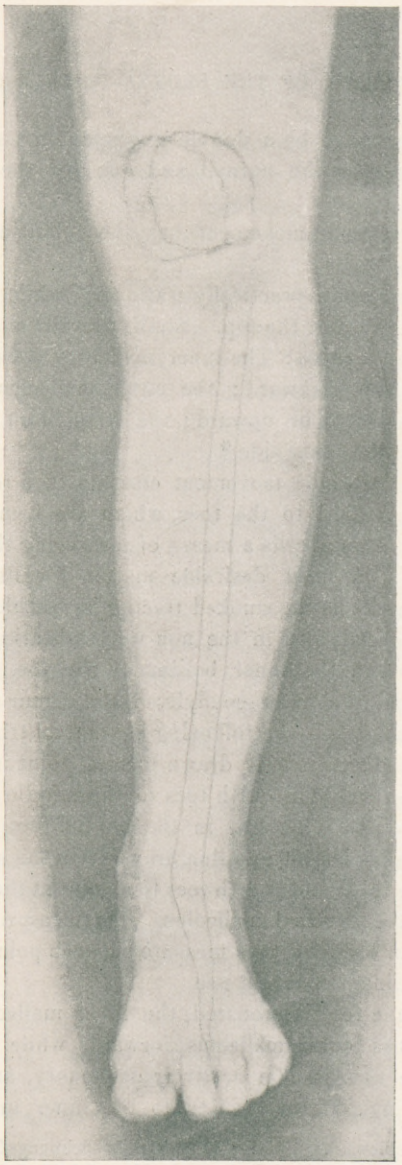

FIG. 4.—A composite photograph of the normal and pronated positions of the left leg. This shows that in pronation the whole leg rotates inward on a vertical axis, while the toes remain stationary, as shown by the excursion of the longitudinal line.

decidedly longer than the line to the outer. If this variation does not exceed one twenty-fifth or thereabouts of the

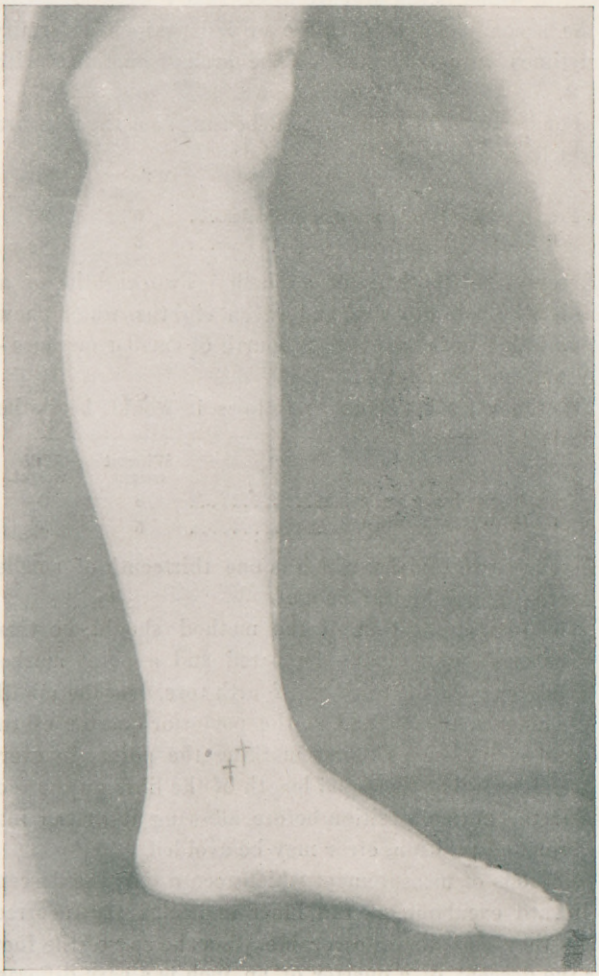

FIG. 5.—Composite photograph showing that the cross over the inner malleolus in pronation moves downward and backward.

shorter measure, it may be considered as the normal amount of pronation, whereas from one twentieth up to one seventh, which is the highest grade that I have measured, is the accompaniment of more or less serious deformity, sometimes with flattening of the arch, sometimes without it.

For instance, in a non-weight-bearing foot the measures might be as follows:

	Without weight.	With weight.
From point at toes to internal malleolus....	6	$6\frac{1}{8}$
" " " " outer " ...	6	$5\frac{7}{8}$

Difference, two eighths of an inch. Two eighths of an inch is divided into five and seven eighths, which shows the variation to be one twenty-fourth of smaller measure—only a normal amount.

If the variation were as follows it would be pathological:

	Without weight.	With weight.
From toes to inner malleolus.....	6	$6\frac{1}{4}$
" " outer "	6	$5\frac{3}{4}$

Difference, two fourths, which is one thirteenth of smaller measure—a pathological amount.

The real application of the method should be this: The patient's foot should be bared and a point marked with ink between the third and fourth toes, over the middle of the inner malleolus, and at the posterior quarter of the external malleolus. By first marking the points in every case and verifying the equal length of the lines on the foot held in the normal position before allowing it to fall into the pronated position, error may be avoided.

Methods of measurement which record only the descent or inward excursion of the inner malleolus are incorrect unless they also take into consideration the size of the foot. For the descent of a quarter of an inch is a very different

matter in a foot six inches long from what it is in one of twelve inches.

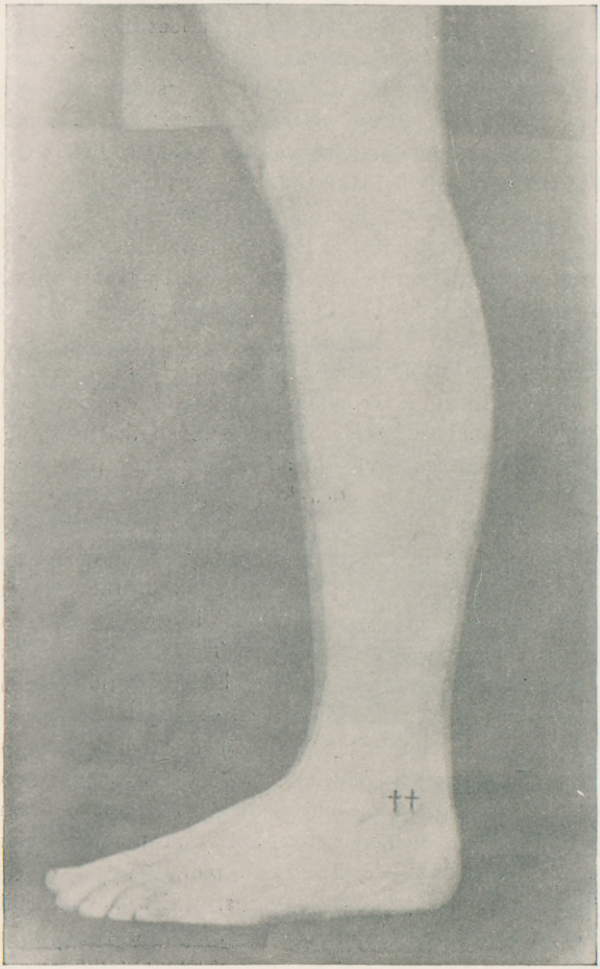

FIG. 6.—Composite photograph showing that in pronation the inner malleolus moves forward.

Finally, I wish very briefly to speak of the anatomical character of this movement of pronation, and I wish to express my indebtedness to Professor Thomas Dwight for his assistance in the study of the movement in the cadaver and on anatomical preparations.

The hip rotates inward, the knee does not participate to any noticeable degree, nor does any lateral movement occur between the astragalus and the malleoli. The movement occurs chiefly between the astragalus and the os calcis, and between these two bones and the scaphoid and cuboid at the medio-tarsal joint, so that the movement really is not to any degree in the ankle, if we mean by that term the astragalo-tibial joint, but in the joints of the foot and at the hip.

It is not possible to analyze accurately any one movement or series of movements in the tarsus, so excessively complicated and so associated with one another are they. Any one who presumes to do so is assuming to do something which is not practicable, on account of the many joints and thier complex surfaces. Consequently it is only possible to state in a general way why abduction of the forward part of the foot and eversion of the sole are necessarily anatomically associated with each other, and why either one can not occur alone. The observations were made by having the model stand with the feet side by side, neither one being advanced, and but slightly separated.

The plane of the medio-tarsal joint is not at right angles to the long axis of the foot, but slants outward and backward. Consequently, movement there which allows lowering of the inner malleolus necessarily at the same time abducts the forward part of the foot. Suppose for a moment that the tibialis posticus, which anatomically seems to be the chief support of the astragalus from rolling inward, becomes tired, and with its accompanying muscles

relaxes. The astragalus and the leg moving as one bone rotate inward on a vertical axis and the astragalus tips its forward end downward, movement at the medio-tarsal joint occurs, and the foot abducts at the same time that it everts; the scaphoid after a little movement between the astragalus and itself moves downward, and its outer end lying above the cuboid, it strikes against it and the whole foot rolls still farther over on this account.

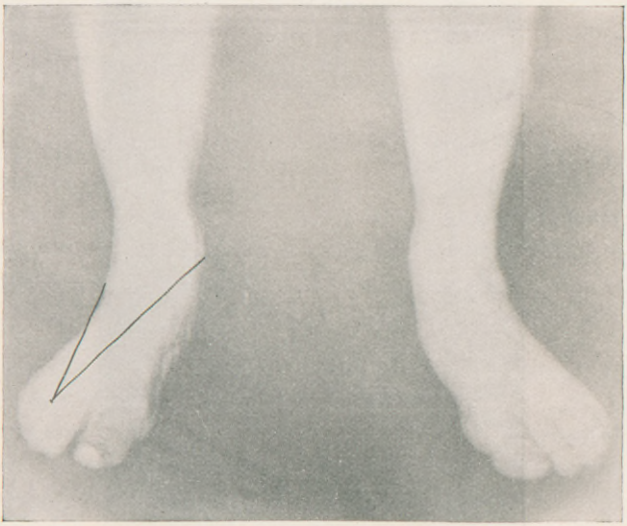

FIG. 7.—The triangle for the estimation of the amount of pronation.

In short, abduction and eversion are clinically and anatomically associated of necessity, and the prevention of one is the prevention of the other, and of all changes leading to pronation and flat-foot. This can be demonstrated as well in the cadaver or in the wet anatomical preparation as in the living foot.

It was interesting to note in experimental work leading up to this paper that the amount of pronation increased

with fatigue. A professional model with an average foot showed at the end of three hours' standing double the amount of pronation that was measured at the beginning.

If you will analyze in your mind the various methods of treating flat foot, you will see that the plate, the pad, the raised inner half of the sole, the brace with a pad or

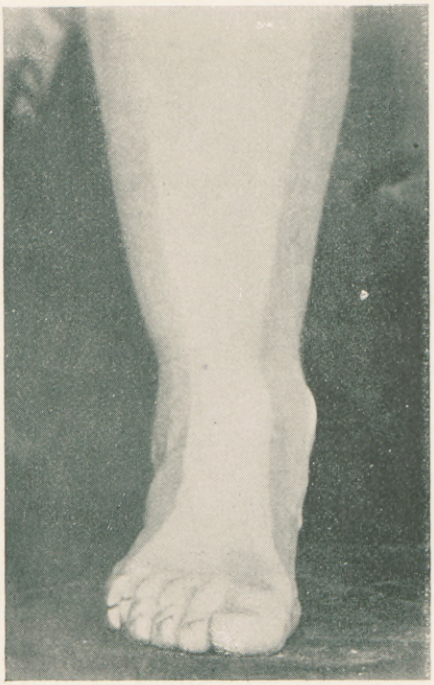

FIG. 8.—A composite photograph showing normal and pronated positions of the foot.

strap over the inner malleolus, all aim at the prevention of eversion of the sole of the foot, which is represented by dropping of the inner malleolus. But I am not here to

discuss so much the treatment of flat-foot as its prevention by the treatment and prevention of excessive pronation.*

First in order comes the use of a proper boot, a boot of the same shape as the human foot, a boot for children with a straight inner edge, a boot for adults to hold the forward part of the foot adducted. For the problem of preventing pronation may be solved in many cases by preventing abduction of the forward part of the foot and not considering the prevention of the dropping of the inner malleolus (eversion of the sole) by any other means.

The essentials of this boot are these:

1. The front part should be strongly adducted.

2. The front part, opposite the metatarso-phalangeal joint, should be as wide in the sole as the weight-bearing foot.

3. The shank should be stiffer and higher than usual and not cut away too much inside. In other words, it should afford real support to the arch of the foot.

4. The inner border of the shoe should be as straight as the condition of the great toe will permit, in order to allow the great toe freedom to support the inner border of the foot in its proper position.

At my original inspection of patients with pronated feet, if they show a degree of pronation exceeding one twenty-fifth or one thirtieth of the shorter measure, I have the soles and heels of their boots made an eighth or a quarter of an inch thicker on the inner side, whether or not they complain of discomfort in the feet from the pronation; the aim being to raise the inner border of the foot until the malleolus falls back into its proper place, and thus the eversion element of pronation is combated as well as the abduction element. If the feet have become painful and must be used, I put a felt pad under the arch of the foot, have the patient douche the feet at night in hot and cold

* Marcinowski. *Zeitsch. f. orth. Chir.*, Bd. iv, H. 1, S. 68.

water, and bandage them with a flannel bandage each night. If this does not give relief, I apply sticking plaster in the method described by Dr. Gibney to hold up the arch of the foot, or I apply metal plates, which I am inclined to think the surest method of affording immediate relief. Plates, as a rule, I only apply as a means of temporary support, hoping to dispense with them later and to substitute muscular support for them. Patients with abnormally pronated feet are directed to walk on tiptoe and to practise adduction of the forward part of the foot against resistance.

I need not comment on the evil effect of the ordinary woman's boot. If one desired to invent a boot calculated to throw the foot over on to its inner side and weaken the muscular support, he would select a boot with a pointed toe, having the point near the middle of the foot; the sole should be narrower than the foot in front; the shank should be weak and cut away inside, and the forward part should not be adducted upon the posterior part. Such a boot crowds the great toe outward and removes a buttress which keeps the inner border of the foot from rolling over. It crowds together the ends of the metatarsals and in general favors both eversion and abduction. The earlier in life such a boot is worn, the greater the harm.

In short, I believe that pronation, with or without flattening of the arch, is the factor to study, and that its prevention and its cure are the prevention and cure not only of flat-foot, but of the painful affection without breaking down of the arch which I speak of as pronated foot; that the selection and use of proper boots will cut down very much the use and need of mechanical appliances. And lastly, I wish to call to your attention the fact that all the work above described has been founded upon the assumption that *eversion of the foot and abduction of the forward part of it are necessarily anatomically associated*, and that the prevention of one is the prevention of both.

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EDITED BY

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