FLAT-FOOT*

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Although the term "flat-foot" is commonly applied by the laity and the profession to the various conditions which cause discomfort in the feet, for the majority of the ailments inducing patients to consult a medical practitioner—or rather to consult a bootmaker or chiropodist, when they ought to be consulting a medical practitioner—it is definitely a misnomer. Nevertheless, it is difficult entirely to avoid terms which have acquired such a wide currency, so the term "flat-foot" has been chosen for this paper, though such an expression as "incompetent feet" would probably be preferable.

Seeing that some estimates have placed the proportion of individuals in a civilized community suffering from foot symptoms as high as 70 to 90 per cent., it is a subject well worth study from the financial and humane points of view. Unfortunately, though the principles involved are simple, their practical application will not be found easy. There are many types of defect, and, moreover, the equilibrium of the foot mechanism is disturbed by such very slight mechanical alterations that to produce accurate balance is most difficult. It is my aim not so much to provide a fool-proof method for the treatment of all foot defects, as to encourage a more careful consideration of a subject that is too apt to be left by the profession in the hands of unqualified experimenters, whose primary outlook is commercial.

CAUSE OF FUNCTIONAL INCOMPETENCE

The functions of the normal foot, which is certainly one of the most marvellous machines in Nature, are: weight-bearing during standing and locomotion, the provision of a spring to reduce jars and assist propulsion during movement, and action as a pivot to assist the turning of the body. There are few movements which do not combine all three of these. An important point, often overlooked, is that these functions do not reside primarily in the foot itself, but in the brain and spinal cord, so that an anatomically intact foot does not ensure a perfectly functioning foot. This is where our friends the bootmakers fail to comprehend the position, and also explains why so many family practitioners rashly cheer anxious parents by assuring them that their child has a perfect foot, and that the orthopaedic surgeon is making a fuss about nothing. This paper is concerned with a particular application of the general thesis, so admirably brought out in Dr. Charles's presidential address, that integrity of structure and function are not identical.

Nothing is more startling than to examine the painful foot of a convalescent pneumonia case, probably a young foot, perfectly proportioned and displaying an admirable arch as it lies on the bed. When the patient stands up the inner border of the foot is seen to sink to the ground in an attitude just as deformed, as that of a congenital calcaneo-valgus. Unfortunately, very few practitioners are on the look out for this initial functional error, and it is only after many months or years, when the deformity has become rigid, and when a faulty habit makes restoration slow, that the patient seeks treatment for a perfectly preventable condition. No patient should get up after acute illness in soft "bedroom slippers," but should wear a firm boot or shoe with laces.

Any factor which depresses the nervous system as a whole, or the muscles locally (by interference with their

blood supply), is liable to cause flat-foot. An anatomically sound foot may thus become functionally incompetent under the influence of:

1. Toxins (a) of acute illnesses, especially pneumonia, diphtheria, and scarlet fever; (b) chronic sepsis, such as foci in the tonsils or teeth.
2. Lack of oxygen.
3. Excessive heat—for example, in stokers, etc.
4. Excessive cold, general, or more especially local—for example, "trench feet" and when shoes and stockings are too thin.
5. General fatigue from any cause—for example, over-marching, standing, hard pavements; shoes unscientifically balanced—for example, those with small high heels.
6. Malnutrition (a) general, especially vitamin deficiency—for example, in rickets poor muscle tone is associated with abnormal lines of stress due to bony deformity; (b) local, from cramped footgear.

More direct causes of functional, as opposed to mechanical, incompetence are: poliomyelitis affecting the tibialis posticus and anticus; spastic paralysis, whether from cerebral haemorrhage or congenital causes; congenital deficiency of the invertors and calf muscles (calcaneo-valgus), the exact opposite of typical "club-foot," and often found associated with an equino-varus club-foot on the opposite limb.

ANATOMICAL CONSIDERATIONS

The numerous small bones of the foot and the joints connecting them to one another, tiresome as they were in our early student days in virtue of their names and relations, are still likely to trouble us to the end of our careers, because the significance of their association does not at once become obvious as we study them more thoroughly. One may summarize this tedious piece of anatomy as follows:

The ankle-joint is almost a pure hinge-joint, moving upward into dorsiflexion, the amount of which varies enormously in different individuals (angles of from 90 to 45 degrees between foot and leg), and downward into plantar flexion, which also varies, but usually allows the top of the foot to be brought into line with the front of the leg. The ankle has this important peculiarity: that dorsiflexion can be limited by the tendo Achillis, which is most taut when the foot is brought slightly inwards, and accordingly strain on a tight tendo Achillis tends to pull the foot into an everted, valgus position; while, if one desires to stretch the tendon to the maximum extent, one must do so with the foot inwards. On the contrary, in an untreated congenital club-foot, the tendon is displaced inwards in relation to the ankle, and is most relaxed in this position, becoming tighter in eversion. After treatment the normal relation usually recurs.

The subastragaloid joints, next below the ankle, allow movements chiefly between the astragalus and os calcis—that is, allow the heel to be rocked inward (inverted) or outward (everted) about a horizontal axis, roughly at right angles to that of the ankle-hinge. This joint, the range of which varies with different individuals, may be considered the key to the function of the whole foot below the ankle. Its normal attitude of slight inversion during weight-bearing is maintained in direct opposition to gravity (that is, the whole body weight) by two muscles—the tibialis posticus and anticus—so that it is very sensitive to slight defects of muscle tone or faults of muscle balance. The muscles acting on it favoured by gravity are the peroneus longus and brevis. If these once gain the preponderance, no mechanical adjustment to the front of the foot will restore the normal relation of the foot to the leg. Conversely, if this subastragaloid joint is maintained correctly, whether by appliances or

* Paper read before the Bath and Bristol Branch of the British Medical Association, November 25th, 1931.

by a fusion operation, the rest of the foot tends to take up the normal attitude, and only fails under the influence of very severe stress. As a general rule, this point is entirely ignored by the bootmaker.

The mid-tarsal joints represent the next important series—the transverse ones between the back of the foot (ankle and heel bones) and the cuboid and scaphoid, and, via the latter, the cuneiforms. This important group of joints acts almost as one, while all those in front of it, between the carpus and metatarsals, assist chiefly in making the foot an elastic structure, and allow very little displacement of one part on another. These mid-tarsal joints produce a complex movement, partly of inward displacement of the front of the foot on the back (adduction, or outward abduction), partly of rotation in association with the subastragaloid movements, and finally, of a dropping of the front on the back, a type of plantar flexion, which becomes exaggerated in the presence of an ankylosed ankle, the stiffness of which is masked by it. It is also obvious in *cavus* conditions of the foot, both the congenital type and that following infantile paralysis. These tarsal joints give elasticity to the foot on uneven ground; but it is perilous to keep them constantly rocking on the perch of a high heel. The various movements described here are difficult to analyse in a normal foot; but disease processes often dissect them in the most striking way. Unless their nature is appreciated, no system of treatment for foot inefficiency can be considered scientific, nor is the result likely to be permanently successful.

Toe movements can also be analysed into two groups: those at the interphalangeal joints, and those at the metatarso-phalangeal joints—far the most important. The interphalangeal are flexion and extension, the former produced by the long tendons. Plantar flexion of the metatarso-phalangeal joints is effected by the intrinsic sole muscles, extension by the long tendons. Like the lumbricals of the hand, those of the foot extend the distal joints at the same time as they flex the metatarso-phalangeal ones.

MECHANICAL PRINCIPLES INVOLVED

Although, as has been said, the different parts of the foot mechanism may be analysed by disease, in health these parts act as a whole. In fact, the knee, hip-joint, and whole lower limb form one complex machine, of which the parts cannot be dissociated without loss of efficiency; indeed, it would be truer to say that the whole muscular and bony systems of the body, co-ordinated by the central nervous system, form an organic whole in locomotion. Accordingly, to treat one part, such as the foot—let alone one toe—is to court failure; yet this is quite commonly done.

One is very apt to think of the foot, when one sees it with the patient on a couch, or in the dissecting room, as consisting merely of small parts moved by small muscles. It should be remembered, however, that in the upright position the feet are subject to the stress of the whole body weight, and that at a point in the cycle of walking one foot is bearing it all. A 16-stone patient may have a foot no larger than a child of 12, and thus one of the most vital considerations in restoring the function of a foot is to reduce the unavoidable stress to which it is constantly subjected from above. If we can reduce the body weight, or improve its balance by posture re-education, we have gone far to solve the foot problem. Coming a little lower, we must consider the relation of the hip to the foot. A position of constant external rotation, whether postural or fixed, will deflect an undue share of the body weight on to the inner border of the foot, and so disturb the normal muscle equilibrium very unfavourably. Fixed internal rotation, by favouring the anti-gravity muscles, is much less serious.

The common causes of external rotation are:

Congenital dislocation of the hip, whether unreduced or reduced.

Coxa vara, whether due to slipping of the epiphysis, fracture of the neck of the femur, or bending by rickets, etc.

Arthritis of many types.

The knee-joint is the one which most intimately affects the mechanics of the foot, and usually deformities of the femur only react on it after the stress resulting from them has distorted the knee. It is a remarkable thing that bowing of the knee (*genu varum*) and knocking (*genu valgum*), if of any severity, both have the same effect on the foot of throwing it into valgus, and so straining the arch. A mild degree of bowing in a muscular subject may not do so, but it is uncommon to find such a combination. The difference is that attempts to restore the inversion of the foot mechanically have to be guided with extreme care in the bow case, or else they aggravate the condition of the knee. A recurvate knee also allows weight to fall on the wrong part of the foot (and vice versa).

Deflections of the limb below the knee (that is, in the tibia) are usually due to rickets or malunited fractures. Forward and backward bowing affect chiefly the ankle- and knee-joints, and are more serious in their effects on the latter than on the ankle. Lateral deflections throw the stress on the all-important subastragaloid joints, which, as already pointed out, are extremely sensitive to the least alteration of alignment. Fractures of either, or both, leg bones therefore represent a serious threat to the future function of the foot, and must always be handled with the most scrupulous regard to alignment in relation to both ankle and knee. Too often one is shown *x* rays which include solely the site of fracture (sometimes only in one plane), and though the fragments may be end-to-end and appear in line, no surgeon can guarantee by such an examination that future function will be perfect. The leg must be matched to the sound limb, not to some imaginary normal. At the same time, it must never be forgotten that the foot mechanism includes muscles and blood vessels as well as bones, and a form of treatment which sacrifices the demands of the muscles and tendons for exercise, together with the circulation, in the supposed interests of accurate bony union, cannot be considered first-rate. Fortunately, the ambulatory plaster, with or without a metal patten, meets most of these demands.

Apart from bone conditions and from muscle deficiency, there are two muscle conditions in the leg which mechanically produce flat-foot. These are: shortening of the extensor longus digitorum, often from injuries such as scalds and deep burns; and shortening of the tendo Achillis, from any cause. The mechanics of the latter have already been discussed.

COMMON COMPLICATIONS

Before discussing treatment, it is wise to consider the complications of foot strain, for many patients consult a doctor for the complications alone. It is most unwise only to treat the latter, without recognizing and dealing with the primary cause.

Common among them are corns in variable sites. Even in very young children the chief evidence of foot incompetence may be a corn under the head of the first metatarsal, a spot which should rarely touch the ground. When seen untired in the consulting room the child may not stand in the valgus position, but the corn will prove that the habitual stance is faulty, as will a hole in the sole of the shoe in the same region. A corn on the inner side of the great toe usually means the wearing of shoes which are too short. Corns under the heads of all the

metatarsals represent failure of the intrinsic muscles of the sole to keep the toes flexed and the transverse arch up. This fault is sometimes the first stage in adults whose other muscles are good, so that the normal tilt of the heel is held. In such, the arch pad under the necks of the metatarsals is sufficient support, whereas in patients whose heel balance is faulty, such support is useless alone—another point usually overlooked by the so-called “surgical bootmaker.” A corn on each internal malleolus, or even a dirty mark, is a sure sign of a valgus position of the heel.

Arthritis of the first metatarso-phalangeal joint, which is usually associated with stiffness, especially to dorsiflexion, is the reaction of this joint to constant weight-bearing, for which it was never designed. In children such a complication as a rule only arises in an individual subject to rheumatism elsewhere, or at any rate possessing septic tonsils. In adults it is most marked in individuals with other joints involved, but may be the only manifestation of rheumatism, possibly because it gets a greater weight than any other joint. The inflammation is usually associated with stiffness, either from muscle spasm, or internal adhesions, or, in the late stages, bony spurs (hallux rigidus).

Subluxation of the first metatarso-phalangeal joint (hallux valgus) usually follows arthritis, but may come merely from the shoe or stocking being too short, or from paralysis of the abductor hallucis. Subluxation of the inner part of the head of the astragalus downward, and in severe cases right down to the ground, is initiated as soon as the os calcis tilts into valgus. It is rarely a fixed deformity, but is very severe in the congenital type of flat-foot. Subluxation of the heads of all the metatarsals downward (one type of claw-foot) is common, and is the cause of the corns already mentioned. If the sole muscles are completely paralysed it cannot be cured by non-operative measures. The congenital type is associated with a cavus foot (that is, too deep an arch), the reverse of the flat-foot type.

Spasm of the peronei (spasmodic flat-foot) sometimes comes on in the late stages of a postural flat-foot, starting with muscle fatigue, or faulty balance from old rickets, but it is considered by the greatest authorities to be usually a disease by itself, whose etiology is most obscure. Spasm of the tendo Achillis and shortening may follow long-standing flat-foot, though probably it is more often the insidious cause, as already explained. Adhesions in any or all of the foot joints are common in flat-foot cases, either as the result of some original injury which started the flat-foot, or as representing a mild arthritis. In any case they are often the cause of the pain complained of, and, until they are broken down, mere restoration of balance will give the patient very little relief.

GENERAL TREATMENT

The symptoms of foot-strain are legion, being either localized in any one of the exhausted muscles, or resulting from the complications already referred to. They may also occur in the sites of secondary strain, such as the back, knee, or hip.

All the above considerations suggest in themselves the lines of treatment—that is, first and foremost, restoration of muscle balance by attention to: general bodily posture and adequate rest; suitable diet with adequate vitamins and fresh air, etc.; correction of any faults of alignment in the limb (as in knock-knee, by calliper or knee-cage; bony faults by osteotomy); and exercises to re-educate the inversion of heel; also heel-and-toe walking. The other important factor is local rest for the foot, by foot-gear with ample toe room (length as well as breadth, with large heel; close fit to instep; laces). In cases with acute pain or severe dropping, strapping should be used to

hold the heads of the metatarsals together and assist the tibialis anticus. If the strapping is missed when removed, a substitute can be found in a well-shaped pad of soft grey felt, sewn underneath a thin, stiff insole. The types of pad on the market are seldom satisfactory. The felt ones are ill-shaped; the sponge-rubber ones yield too much. When the foot can take up so much spring it does not need a pad; the type it needs corresponds to the padding of a horse's saddle.

When, as is usual, the chief fault is the outward slope (eversion) of the os calcis, the joint can be given constant rest by crooking the heel of the boot, or lace shoe, by an inside wedge. A strap shoe or sandal does not take enough grip of the foot to keep it on the crook, so this only adds to the instability, and is dangerous. The boot is usually most comfortable if a very small wedge is also added to the sole under the first metatarsal head—not all along the sole. The aim is to make the patient walk, not on the outer edge of the foot, which is an abnormal procedure, but with the arch raised. In children this crooking acts like magic, but with adults it must be used with all sorts of precautions, which cannot be discussed in a short paper of this kind.

METHODS IN DETAIL

As regards treatment of the complications, corns must not be referred to the chiropodist for removal till the strain has been removed from the site of their origin, for they are the protection afforded by Nature to the affronted bone. When the stress is gone, one application of salicylic collodion is usually enough to send them away. A hallux rigidus in the state of spasm must be rested by a spica of strapping in as much dorsiflexion as possible; in the later stages the adhesions must be broken down rigorously till the dorsiflexion is equal to that of the sound side. An early hallux valgus must be treated similarly; a late one demands operation, if symptoms persist after the foot strain is dealt with. After operation, relapse can only be avoided by using correct footwear. Therefore it is wise, if the surgeon has any care for his own reputation, to insist on this first.

Adhesions should be broken down without an anaesthetic whenever possible, to avoid the danger of causing fresh trauma by the use of excessive force. They must be dealt with systematically, joint by joint, and one must never be satisfied until a range equal to that of the good side has been attained, and the patient is able to carry out that full movement himself. The treatment may need several sessions. Each time some swelling and reaction are likely to occur, but they soon go off with hot baths or contrast baths; and, as soon as one reaction is settled, it is safe to begin again. One can do each time as much as the patient will stand. Mennell's method is of great value; namely, to carry out movements across the axis of joints—movements for the performance of which no muscle exists. One must have the patient lying relaxed, so that resisting muscles are not torn. A tight tendo Achillis requires similar handling, but some can only be adequately stretched under anaesthesia. One must not forget the importance of inversion of the foot, already mentioned. Peroneal spasm rarely yields without anaesthesia, and often it is best to excise over an inch of each tendon, for they unite most rapidly and relapse into spasm. Even after excision, one may be unable completely to invert the foot owing to shortening of ligaments; but symptoms will generally have been relieved, as one finds on the removal of the plaster some six weeks later. The extreme dropping of the inner side of the foot in some congenital and rickety cases is improved by prolonging the inner side of the heel (but to a greater degree than on the “Startrite” shoes); or, alternatively, one can use an inner boot of hard leather which has been moulded

on a corrected cast of the foot. In very severe and neglected cases, which are stiff and painful—that is, have not a bony ankylosis—it is wise to arthrodesis both subastragaloid and mid-tarsal joints, thus imitating Nature's method of spontaneous cure.

As regards exercises, those done on tip-toe are bad, because they aggravate the shortening of the tendo Achillis. The tibialis anticus and sole muscles require cultivation by lifting marbles, pulling towels, etc. It is then necessary to re-educate the heel-and-toe walk, as revealed by cinema analysis to be the normal.

THE BLOOD SEDIMENTATION RATE IN PULMONARY TUBERCULOSIS ITS VALUE IN THE MANAGEMENT OF THE PATIENT

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Though it is generally accepted that the sedimentation rate of the red blood corpuscles is of definite value in the prognosis of pulmonary tuberculosis, the importance of this test as a guide to the regulation of rest and exercise does not yet appear to have received due recognition. This paper suggests the value of repeated estimations of the blood sedimentation rate (B.S.R.) in the above connexion.

Just as repeated recordings of the temperature and pulse rate are essential in pulmonary tuberculosis, so must estimations of the B.S.R. be repeated for the intelligent application of the information provided. Monthly tests are usually sufficient. During three years I carried out some 729 estimations of the B.S.R. on 244 patients. I have always employed the Westergren method, by which 1.6 c.cm. of blood is drawn into a 2 c.cm. syringe already containing 0.4 c.cm. of a 3.8 per cent. sterile solution of sodium citrate. All apparatus should be clean and dry, and the citrated blood, previously mixed by shaking and inverting, should be sucked up into the Westergren tube a few seconds after withdrawal. With platinum needles (size 16 or 17) frequently sharpened and having a flat bevel of medium length, no difficulty has been experienced in venous puncture. In the great majority of cases it is sufficient for practical purposes to read, at the end of the first hour only, the height in millimetres of the clear plasma above the red cells. Until the readings are complete the apparatus should be kept in a constant temperature of approximately 65° F. Cold retards the rate, warmth increases it.

Since altitude has the effect of diminishing the total mass of blood, there is an apparent increase of the red cells. This seems to modify the sedimentation of the cells in such a manner as to render the rate slower. All my estimations have been carried out at an altitude of 5,000 feet above sea-level. I have investigated the B.S.R. in but twenty apparently healthy individuals, and have never found a higher figure than 3 for the first hour in men and 4 in women. The usual figure is 2 in either sex. I assume a rate of under 4 to be normal in men and under 6 normal in women. It is desirable to avoid an estimation a few days before, during, or a few days after menstruation. Readings of from 4 to 15 in men and 6 to 15 in women I regard as representing a slight increase of the B.S.R. From 15 to 30 is a medium increase, from 30 to 50 a marked increase, and over 50 a very marked increase. This grouping is entirely personal and arbitrary. Low rates are generally regarded as of good prognostic

significance, though in emaciated patients with very advanced disease relatively low readings are almost invariable. The most likely explanation for the latter is that in cachexia the blood shows diminution of the fibrinogen and a lowered concentration of the serum protein. Increase of fibrinogen and serum globulin in the blood plasma is probably the most important factor in the production of an increased rate. In some individuals, more usually in women and most commonly in patients of a "nervous" temperament, it occasionally happens that the temperature will not quite settle within the usual limits of normality, and yet the B.S.R. is normal, or very nearly so. This may be apparent after the patient has had a more or less prolonged period of rest. While the temperature record might cause doubts as to the presence of activity, the B.S.R. in such cases confirms the physician's opinion, formed from other sources of information, that the extremely slight rise of temperature may be disregarded. When it is decided to allow these patients to move about and take exercise the temperature will usually settle to normal. From time to time normal readings occur in patients with a positive sputum. From the practical point of view the majority of such patients, particularly if the readings are consistently normal, may be regarded as little more than "carriers."

My experience of the B.S.R. in prognosis is that repeated estimations undoubtedly help in making more accurate the forecasts based on all the other available data. Prognosis will depend largely on the nature of the disease, the patient's resisting powers, the economic factor, the patient's temperament and character, and the response to any special treatment. Persistent rates in the "medium" group, or unstable rates, will tend to make the prognosis more or less guarded according to the varying significance of the other factors in each case. The persistence of "marked" or "very marked" increases in the rate over a prolonged period (six months or longer) generally indicates a bad outlook, even though such patients may remain afebrile for several weeks or months at a time.

BLOOD SEDIMENTATION RATE IN REGULATION OF REST AND EXERCISE

In pulmonary tuberculosis relapses, such as a rise in temperature and other signs of increased activity, an haemoptysis, or a pleurisy, etc., are commonly encountered. Prior to their onset the patient's temperature (including exercise reactions), resting pulse rate, general condition, and appearance may have been quite satisfactory, and even the exercise tolerance may have been high. In the absence of any special therapeutic means to prevent them, these relapses are apt to be regarded as unavoidable developments of the disease. This interpretation is undoubtedly true of a certain number of cases, but there is a not inconsiderable proportion of patients who may be spared such disappointments if the physician will, even in the presence of normal temperatures and pulse rates, greatly limit their activities until the B.S.R. has dropped to within the "slightly increased" group. The degree and duration of such limitation will vary with each individual case according to clinico-pathological, psychological, and other factors. In young patients with recent histories I generally prefer to wait until the B.S.R. has reached single figures before beginning exercise, particularly if the other factors suggest prudence.

As the B.S.R. is largely an index of the activity of the disease, its use in the regulation of the patient's activities would appear to have a rational basis, provided that it is interpreted with due regard to all the other evidence. The advantages of its use as a control over one's judgement in prescribing rest and exercise—some-