G.P. Review Article

FLAT FOOT: I*

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SUMMARY

The symptoms of flat-foot do not at all correspond with the degree of deformity, and the diagnosis of the condition is frequently erroneous. The features of the normal foot are described, and a method of examination is outlined. The pathological types of flat-foot will be the subject of a further review article to be published at a later date.

In his 'Observation of forty-five cases of flat-foot with particular reference to etiology and treatment', Royal Whitman (1888),[1] commented as follows: 'The symptoms . . . do not at all correspond with the degree of deformity. Many persons with complete flat-foot have no trouble, while others who are practically disabled by it show but a slight flattening of the arch.'

Hoffman (1905)[2] made a comparative study of the feet of bare-footed and shoe-wearing peoples, and with a single illustration (Fig. 1) succeeded beyond words in making his point. Here indeed is the example *par excellence* of feet which, although literally flat, cannot be regarded as flat-feet in the pathological sense. Whitman's words have stood the test of time and his treatise has been labelled 'the classic'. They have nevertheless failed to gain universal recognition, or to prevent an erroneous diagnosis of flat-footedness in countless individuals, who have been condemned to a life of inactivity on the flimsy grounds of a relatively low longitudinal arch. In a sport-loving community this factor can prove a serious handicap, and can lead to psychological tension and physical disability.

Fig. 1. The feet of a primitive tribesman, apparently flat, are healthy and within normal limits. (From Hoffman.[2])

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A narrative which has a ring of truth serves to re-emphasize the point: a group of tribesmen tramped the breadth of a continent in order to enlist for military service. They were submitted to medical examination and rejected as unfit on the grounds of 'flat-feet'. They tramped all the way home again, a distance of 3 000 miles, without physical discomfort! It is a strange yet an undoubted fact that while no medically unqualified person would venture a diagnosis of 'pes plano-valgus' or 'pes calcaneo-valgus' few would hesitate to dub a child or an adult 'flat-footed'. It follows that the very term 'flat-foot' has to some extent become meaningless, and has given rise to much confusion of thought. When one recalls the truism in respect of head injuries expressed by Hippocrates, that an injury of this nature is 'neither as trivial nor as serious as it appears to be', then one might with equal truth claim that a foot is neither as flat nor as arched as it appears to be.

THE NORMAL HUMAN FOOT

The foot is a non-rigid structure adapted for bipedal use in the act of standing and walking. It adopts varying forms during its growth from infant to adult stage, and also while performing its normal functions. It conforms to no fixed anatomical pattern but varies within a limited range and in its several aspects, each of which is studied in the course of a routine examination.

The Anteroposterior Aspect (Dorso-plantar) (Fig. 2)

The medial border of the foot presents as a hollow concave outline (Fig. 2(a)), but may vary under differing conditions. Variations in outline are an expression of the range of movements at mid-tarsal and subtaloid joints.

During weight-bearing, and with voluntary efforts at 'arching' of the foot, the medial border may become slightly convex (Fig. 2(b)), or hyper-concave (Fig. 2(c)), in shape, still within normal limits.

The criterion of normality is not the physical shape of the medial border but rather the ability of the individual to assume each of the different forms with voluntary and even involuntary effort, and with neither pain nor discomfort. An outstanding example of the flexibility and mobility of a normal healthy foot may be seen in the young and the athletic. A ballet dancer in his prime (Fig. 3(b) and 3(c)) can scarcely be labelled 'flat-footed', yet first impressions might be deceptive.

The Medial Aspect (Fig. 3)

The height of the longitudinal arch varies even as the medial contour of the foot, and cannot be expressed in terms of a measurement upon a scale. It can be 'raised' or 'lowered' at the will of the healthy individual and it undergoes involuntary variations during the differing

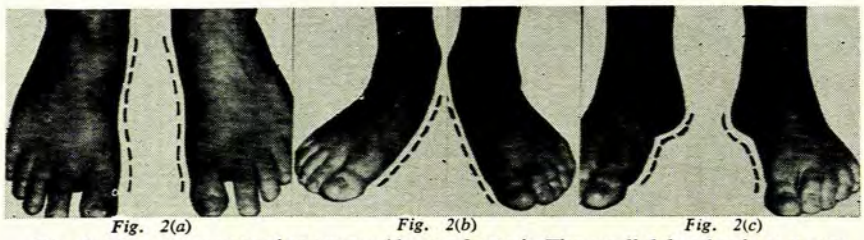

Fig. 2(a) *Fig. 2(b)* *Fig. 2(c)*

Fig. 2. The anteroposterior aspect (dorso-plantar). The medial border is concave (*a*), but may vary from an outline of slight convexity (*b*), to one of increased concavity at the will of the individual (*c*) and without pain or discomfort.

phases of the gait, static posture, and at rest.

The powerful nature of the muscles controlling the digits, the ankle and the foot can to some extent be gauged by a study of the ballet dancer's feet (Fig. 3(c)). In a careful study of the functioning foot during the act of walking, of running and of standing, the variability of form and the smooth power of control will be readily apparent. The mid-tarsal joints are mobile within the following range[3] (Fig. 4):

Inversion (supination)—35°
Eversion (pronation)—15°
Abduction—10°
Adduction—20°

In the infantile and juvenile foot, the range of movements is greater than in the adult, while in the aged foot the

Fig. 3(a)

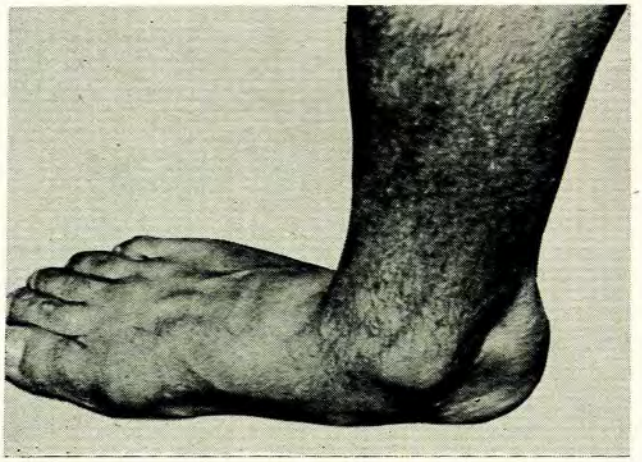

Fig. 3(b)

Fig. 3(c)

Fig. 3. The medial aspect. The height of the longitudinal arch varies in normal individuals, and in the same individual under varying conditions. The arch may be voluntarily raised during the act of standing (*a*), or voluntarily depressed (*b*), or it may display average proportions (*c*), without pain and without effort.

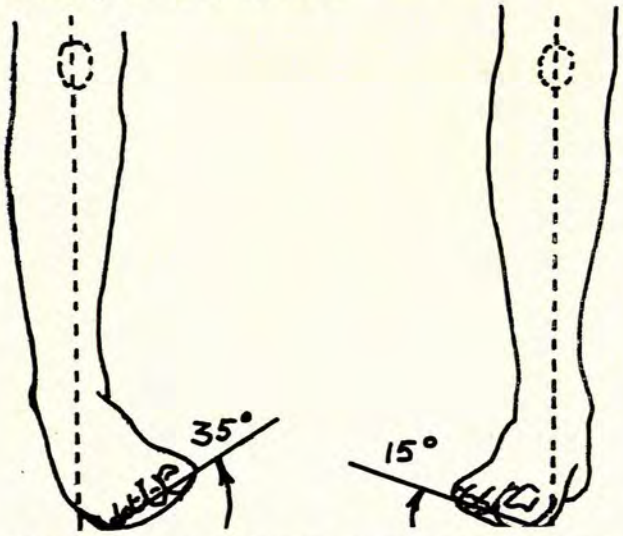

Fig. 4. The range of inversion and eversion at the mid-tarsal joints permits mobility from 0 to 35° for inversion and from 0 to 20° for eversion.

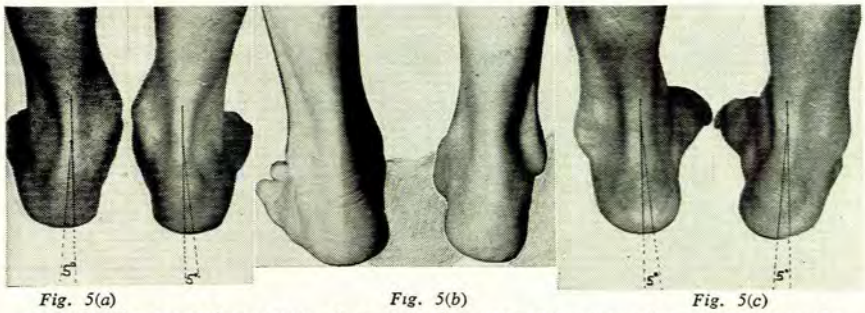

Fig. 5(a) *Fig. 5(b)* *Fig. 5(c)*

Fig. 5. The posterior aspect. A range of movements amounting to 5° from the vertical in either a medial or lateral direction is within normal limits.

movements are diminished by the degenerative changes in joints as well as in ligamentous and muscular structures. In the assessment of the foot and the range of normal movements, the age of the patient must be considered.

The Posterior Aspect (Fig. 5)

The heel bears a relationship to the vertical which varies from 5° of inversion to 5° of eversion i.e. within a range of 10°. The position of eversion (Fig. 5(a)) is usually adopted while the patient stands at ease, while inversion of the heel involuntarily occurs during the act of standing on the toes (Fig. 5(b)).

Inversion of the heel may be a voluntarily action which in the normal foot is accomplished painlessly and with minimal effort (Fig. 5(c)). A position of fixed inversion or fixed eversion of the heel indicates a pathological condition. Eversion of the heel is an integral feature of pes plano-valgus.

The Foot at Rest

With the patient seated, the following data may be obtained:

The length of the Achilles tendon. When the tendon is of normal length, extension of the ankle is possible to a position of 20° above a right-angle (Fig. 6(a)). In the presence of a moderate degree of shortening, extension takes place to a right angle only (Fig. 6(b)) when shortening is of a more severe degree, then the ankle adopts a position of plantar flexion, referred to as 'equinus'

Excessive length of the tendo calcaneus is associated with an increase of extension at the ankle and with a calcaneus deformity. The degree to which extension at the ankle joint is possible can be assessed with accuracy only after the mid-tarsal joints have been excluded as an accessory factor. This is acomplished by 'locking' the mid-tarsal joints in a position of forced inversion (Fig. 6(b)), then placing the ankle in a position of forced passive extension. Shortening of the tendo calcaneus results in a deformity of the foot which is referred to as 'valgus ex equino' (Fig. 6(c)). Because the treatment of this type of flat-foot is specific to the condition, the clinical recognition of 'valgus ex equino' is of prime importance.

The developmental state of the hallux metatarsal. The normal first metatarsal bone is marginally shorter than the second, it is considerably heavier in structure and it bears an angle with the shaft of the second metatarsal bone

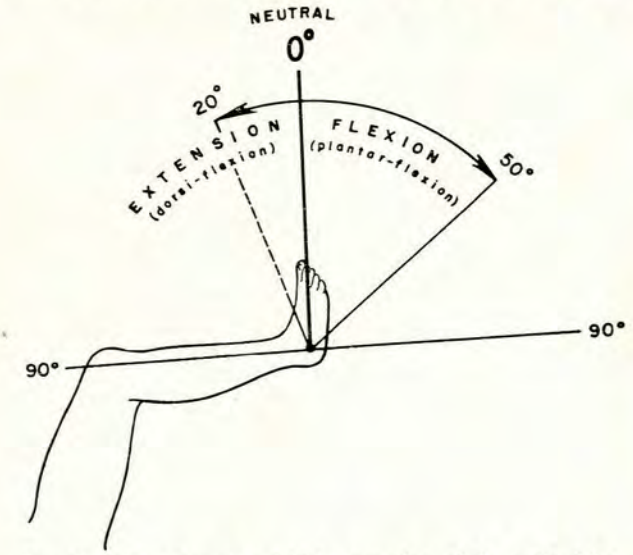

Fig. 6(a). The degree to which extension of the ankle joint is possible is a measure of the length of the tendo calcaneus.

Fig. 6(b). With the mid-tarsal joints excluded as a result of being 'locked', the length of the tendo calcaneus may be tested.

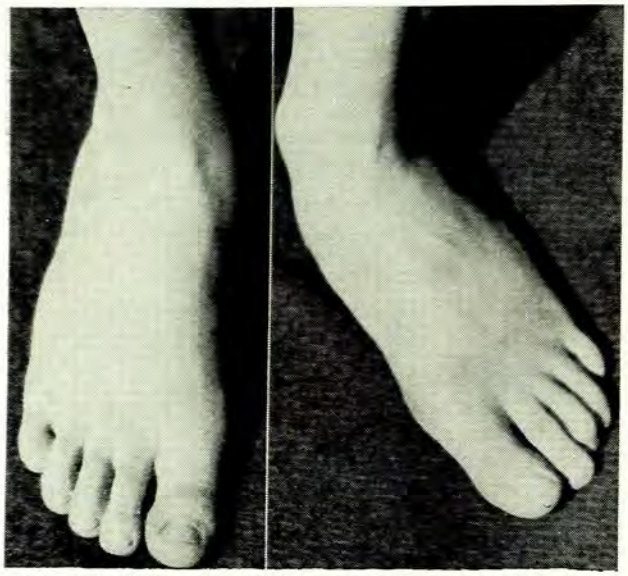

Fig. 6(c). Shortening of the tendo calcaneus results in a deformity referred to as 'valgus ex equino', left foot above.

which does not exceed 7° on radiographic examination. Congenital variations such as metatarsus primus varus (Fig. 7) and metatarsus atavicus constitute obvious deformities which require radiological confirmation.

The condition of the hallux metatarsophalangeal joint is secondarily involved and in the case of metatarsus primus varus it displays hallux valgus deformity.

Fig. 7. Congenital metatarsus primus varus, with secondary hallux valgus. The normal metatarsal I and II angle does not exceed 7°.

The musculature of the foot. Normal muscular strength is necessary to the efficient performance of the foot, and the strength of individual muscles is recorded during a routine examination. The muscles which are significant are:

1. The triceps surae, the most important muscle of the foot.
2. The tibialis anterior, a prime mover in inversion of the foot and extension of the ankle joint.
3. The tibialis posterior for inversion of the foot and flexion of the ankle joint.
4. The peroneus longus for depression of the first metatarsal as well as mid-tarsal eversion and plantar flexion.
5. The peroneus brevis for mid-tarsal eversion of the foot and plantar flexion of the ankle.
6. The long extensors and the long flexors of the digits.
7. The intrinsic muscles which are the main flexors of the metatarsophalangeal joints of the digits.

The intrinsics are essential to a normal 'kick-off' action of the foot during ambulation. Paralysis of the intrinsic muscles results in hyperextension of the metatarsophalangeal joints and hyperflexion of the interphalangeal joints, a condition known as 'claw-toe' deformity (Fig. 8(a)). This condition is characterized by the presence of callosities beneath the metatarsal heads, and on the dorsum of the digits. (Fig. 8(b)).

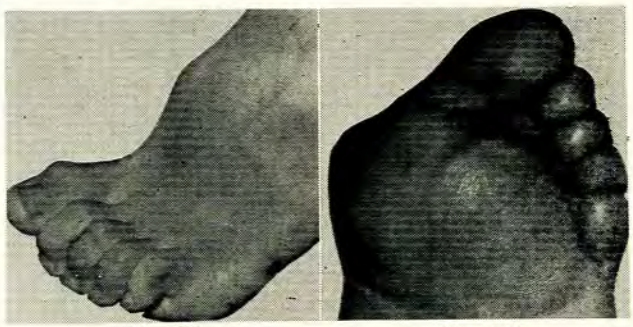

Fig. 8(a) *Fig. 8(b)*

Fig. 8. Congenital claw-toe deformity, with hyperextension at metatarsophalangeal joints and inability to press the toes onto the ground (*a*). The callosities (*b*) beneath the metatarsal heads are incorrectly and loosely referred to as the result of a 'fallen' metatarsal arch.

The importance of the normal action of the intrinsic muscles cannot be over-emphasized for not only does strong flexion at the metatarsophalangeal joints contribute to the 'kick-off' in walking, but it also succeeds in forcing the plantar surface of the digits to the ground, thereby contributing to the total weight-bearing surface of the plantigrade, human foot (Fig. 9).

Congenital abnormalities. Club-foot deformity is recognized at a glance and will be dealt with in a later publication. Accessory ossicles of the foot, notably the accessory scaphoid (Fig. 10), require recognition and noting. The latter is characterized by the presence of a bony prominence at the medial aspect of the mid-tarsal region of the foot, by local tenderness confined to the prominence, and by a tendency to valgo-planus deformity. Depression of the longitudinal arch, together with eversion of the foot,

is the result of the relative ineffectiveness of the tibialis posterior muscle, the tendon of which is attached, partially if not wholly, to the accessory ossicle instead of the parent scaphoid. The condition occurs commonly, but is seldom of serious significance.

Fig. 9. The print of a healthy foot during the gait (*left*), and on standing (*right*). Full participation of the metatarsal heads is the hallmark of a normal foot. The metatarsal arch is not 'fallen'. *Note*: During walking the length of the foot is increased by 1 - 2 sizes in footwear. This is a factor which requires consideration when new footwear is purchased.

Fig. 10. Congenital accessory scaphoid, with associated mild degree of bilateral valgo-planus deformity.

THE TRANSVERSE METATARSAL ARCH

It is a common experience to be informed by a patient: 'Doctor, my metatarsal arch is fallen'. A critical analysis of this complaint is unlikely to support the contention, yet a complaint of painful feet is frequently justified in these circumstances.

When a normal footprint (Fig. 9) is examined, whether that of a child or an adult, then the fallacy of the complaint is immediately apparent because the metatarsal heads all share in the weight-bearing and the 'arch' presents as a plantigrade (flat) surface. While it is an anatomical fact that during the 'kick-off' phase of the gait, the metatarsal heads are relieved proportionately from pressure as the digits come into operation, this is a subtle action which although associated with phasic arching, is not apparent to the lay individual.

Why then is the above complaint so common? I offer a tentative explanation, and will refer again to the illustrations in Fig. 8. Paralysis of the intrinsic musculature of the foot is depicted, with claw-toe deformity and with large plantar callosities. Palpation of the sole in this instance will reveal the prominence of the metatarsal heads which threaten to perforate the skin and which are prevented from penetration by the protective callosities. The metatarsal heads are indeed depressed and the phasic arching at this level is no longer possible because of paralysis or weakness of the intrinsic muscles. The weight of the superincumbent body is borne by the pads beneath the metatarsal heads, which in turn become thin and atrophic. The digits no longer participate and are, in effect, 'passengers' during the acts of walking and standing. Under these circumstances, a complaint of metatarsal arches which have 'fallen' is justifiable, and it is essential that the practitioner appreciates the implications. The remedy consists of restoration, if possible, of the strength of the intrinsic muscles and, if impossible, then by the application of measures aimed at the relief of pressure on the painful callosities.

Another 'metatarsal arch' may be confused with the above, namely the half-arch which the bases of the metatarsals form at tarsometatarsal joint level. Little attention need be paid to this half-arch, which is included in the examination of the mid-tarsal region of the foot and from the clinical point of view forms part of the mid-tarsal joint 'complex'.

Attention is drawn to the impression which the foot makes on the weight-bearing surface during standing and walking (Fig. 9). It will be observed that the length of the foot and of the digits is increasing by $\frac{1}{2}$ - $\frac{3}{4}$ inch in the case of the adult. This factor must be taken into account when new shoes are being fitted, in order that cramping of the toes and a deterrent to normal action of the intrinsic muscles may be prevented.

The study of the normal foot and of the individual features which distinguish the normal from the pathological is beset with pitfalls. The abnormal conditions of the foot which occur commonly in general practice will be the subject of a later review article. The subject of footwear will also be discussed.

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REFERENCES

1. Whitman, R. (1888): Boston Med. Surg. J., **118**, 598.
2. Hoffman, P. (1905): Transactions of the American Orthopaedic Association, 18, 105.
3. American Academy of Orthopaedic Surgeons, Boston, Mass. (1963): *Joint Motion: Method of Measuring and Recording*, p. 73.