THE
CAUSATION AND MODE OF PRODUCTION
OF PES CAVUS.

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THE deformity known as pes cavus, hollow foot, or clawed foot, is one that apparently has not attracted very much attention, and the causation of which has not been indicated very satisfactorily. In fact, not a little confusion exists about its mode of production, and the statements given in books are contradictory and misleading; in many recognised text-books it is not described at all, in others it is disposed of in a few words; and yet cases are by no means uncommon, especially in association with other forms of talipes.

The deformity consists in an increased height of the longitudinal plantar arches, with a corresponding increase in the convexity of the dorsum, the scaphoid and cuboid bones being often very prominent, and occasionally covered by a bursa. The ball of the great toe is more conspicuous than usual, and it, along with the under surfaces of the other toes, is approximated to the heel, so that an antero-posterior diminution of the length of

the foot, varying from a half to one and a half inches, is produced. The central portion of the plantar fascia is thickened and contracted.

Accompanying this condition is a subluxation of the first phalanges of the toes upon the heads of the metatarsals, in severe cases the phalanges being almost vertical; the terminal phalanges are flexed. The tendons of the ext. proprius hallucis, ext. longus digitorum, and tibialis anticus often stand out conspicuously, and an excessive movement of the toes occurs when attempts are made to extend the foot. This condition is almost invariably associated with talipes equinus, and the tibial articular surface of the astragalus can often be felt projecting on the dorsum. Corns develop on the under surfaces of the heads of the metatarsal bones, and sometimes over the first interphalangeal joints.

The explanations given in various books of the origin of this condition may be briefly considered.

The writer in Heath's 'Dictionary of Surgery,' speaking of talipes equinus being due to contraction of the tendo Achillis, says, "In the majority of cases nothing else is at fault, but in some, a further examination being made, the arch of the foot is found unduly flexed and the plantar fascia to be tightly contracted."

In 'Holmes' Surgery' the writer says, "As a substantive deformity I am not acquainted with it [pes cavus]."

Erichsen quotes Duchenne as saying, "When the interosseous muscles are paralysed or atrophied, the tonic contraction of the muscles which extend the first phalanges and that of the muscles which flex the last phalanges being no longer opposed, the claw-like condition of the toes becomes augmented. The posterior extremities of the first phalanges are subluxated upon the heads of the metatarsal bones; then the curve of the plantar arch becomes increased and the plantar fascia shortened," &c.

Mr. Golding-Bird, in the 'Guy's Hospital Reports' for 1883, ascribes the deformity to weakness or paralysis of the peronei muscles. In 'Holmes' System' and in

'Gant's Surgery' I can find no mention of the condition.

That Duchenne is wrong in ascribing the deformity to paralysis of the interossei seems at once evident from the tilting of the toes being only a small part of the affection, and personally I am quite unable to follow out his explanation of how this increases the height of the plantar arch. The extensor proprius hallucis and longus digitorum can only extend the foot when the toes are extended, or when they are fixed by the flexors; and the actions of these muscles must be weakened by the approximation of their attachments.

Besides, this extension of the foot tends to flatten the arch rather than to deepen it. Then, again, no cause for paralysis of the interossei is suggested, and infantile paralysis of these muscles as an isolated condition is scarcely conceivable. A still stronger argument is that interosseal paralysis of the hand does not produce a similar deformity, although the arrangement of muscles is the same.

Mr. Golding-Bird's suggestion that the peronei muscles are at fault would account, perhaps, for the production of talipes varus from over-action of the tibial muscles; but that the over-action of these muscles should be sufficiently great to produce an actual bony deformity of the tarsus seems improbable. Spasm of muscles may cause a temporary deformity, but a permanent change is surely more likely to be caused by fibroid contraction of a paralysed muscle than by spasm of an opponent.

The affection under consideration has been also ascribed to wearing tight boots. That this should produce a diminution in the length of the foot of from a half to one and a half inches is inconceivable, especially as the condition is often unilateral. Another explanation offered is that of the combined over-action of the tendo Achillis and ext. longus digitorum. If this were true we should expect to find the deformity most marked in those who have not walked, as there is always a tendency in walking to

flatten out the arches of the foot ; it will be shown later that this is not the case. That a contraction of the plantar fascia could *per se* cause the deformity is very unlikely ; if it were so we should expect to find the inner portion of the fascia the most thickened. Besides, granting this, what is the cause of the fascial contraction ?

These explanations, which I have taken *seriatim*, are obviously very unsatisfactory, and it is necessary to see whether a better one cannot be offered. In order to do this it will be advisable to consider how the weight of the body in the erect position is supported by the plantar arches.

Referring to Fig. 1, the weight of the body, passing vertically to a point A, is then transmitted to the ground

FIG. 1.

at the points of contact, viz. the heel and the balls of the toes. The weight of the body w , acting along $w A$, may thus be represented as broken up into two components, $A C$ and $A B$, of which $A C$ is the greater. But each of these may be again broken up into a vertical and a horizontal part ; and whilst the vertical components represent the proportion of w which belongs to each, the horizontal components tend together to diminish the height of the arch, as they act in opposite directions.

If now we apply the same process to a case of talipes equinus, Fig. 2, we find that owing to the tilting of the

heel, which cannot be made to touch the ground, the weight of the body is transmitted along AB only, and AC represents a latent force. This force cannot be neutralised by any pull of the tendo Achillis, for this would simply transfer again the vertical portion of AC to the tibia and femur. The action of the contracted soleus and gastrocnemius is simply to limit the movement at the ankle-joint in the direction of extension of the foot. If now A be taken as situated in the centre of the astragalus there is a constant tendency for that point to move nearer C ; and the point B being fixed by contact with the ground, and therefore the horizontal component of AB neutralised,

FIG. 2.

the force AC is constantly tending to bend or render convex upwards the portion of the arch AB . This tendency is resisted by the dorsal and interosseous ligaments of the foot and the shape of the bones of the metatarsus and tarsus. Any muscular resistance must of necessity be small and easily compensated for by muscular or tendinous adaptation.

The force AC tending to produce convexity of the tarsus is not, however, constant; in a position of rest it does not exist, for a patient with talipes equinus will flex the thigh and leg so that the centre of gravity may pass through the point B , *i. e.* through the heads of the metatarsal bones. It is only in walking that the mechanism described comes into play, and it follows from this that a person with talipes equinus would only develop pes cavus after he had been

walking for some time ; and that a patient who does not walk or who is confined to bed would not develop pes cavus at all, but would only have the talipes equinus increased by the weight of the foot. Similarly a patient with talipes equinus who wears a high-heeled boot will not develop pes cavus, the force $A C$ being directly transmitted to the ground.

Considering the mechanical forces further, it will be readily seen that the greater the talipes equinus the less the tendency to develop pes cavus ; so that if the heads of the metatarsals fall directly in the line of the transmitted body-weight, the tendency to formation of pes cavus is nil. This, represented in Fig. 3, is found to be the case

FIG. 3.

in practice, and I have been unable to find any case like Fig. 3 in which there was mention of contracted plantar fascia, &c. Again, the force tending to increase the curve of the plantar arch being greatest as soon as the heel is raised slightly from the ground, it follows that the bending of the arch is really a compensatory change allowing the heel to again touch the ground. When this happens equilibrium is re-established, only to be again rendered unstable by a further contraction of the soleus

and gastrocnemius. This condition of established equilibrium is represented in Fig. 4; and it may be here noticed that, in those cases of pes cavus without any apparent equinus, not only is the tendo Achillis tense, but extension of the foot beyond a right angle is impossible. In the majority of cases, however, compensation cannot occur to a sufficient extent, and along with the pes cavus

FIG. 4.

there is still talipes equinus, which may or may not be associated with varus, and probably in rare cases with talipes valgus, though of the latter I am a little uncertain.

The cause of the talipes equinus varies in different cases; in some it is congenital, in the great majority associated with some talipes varus. In acquired cases infantile paralysis of the soleus and gastrocnemius, followed by fibroid contraction of these muscles, is a common cause. Other causes of talipes equinus need not be enumerated, but it is not too strong a statement to make that any case of talipes equinus, however produced, may be associated with pes cavus, provided only that the patient transmits the weight of the body for a sufficient length of time through the affected foot without the intervention of a raised artificial heel.

The characteristic condition of the toes has from time to time been noticed from its resemblance to "hammer-toe," and hence probably the supposition that pes cavus was due to wearing too short boots.

Primarily the first phalanges are hyperextended—or rather one might say that the metatarsals are hyperextended on the phalanges—when the foot acquires the position of talipes equinus, the condition represented in Fig. 2. Consequently the extensors of all the toes shorten to adapt themselves to the new position. As soon as this hyperextension from position has reached a certain stage (and not only is there hyperextension, but an actual subluxation upwards with expansion of the articular surfaces of the metatarsals) the interossei and lumbricales are rendered inactive, or act in a direction the reverse of normal, because their lines of action are now behind the centre of the heads of the metatarsals: When these muscles act they tend actually to increase the deformity, further extending the first phalanges and not extending the terminal phalanges, which become flexed either by their own weight, by adaptation to the boots, or by the pull of the flexor tendons. This mechanism is obvious on considering the anatomy of the part, and is exactly similar to what occurs in hammer-toe; in fact, Mr. Lane has pointed out in the 'Trans. Path. Soc.,' 1886 ("Causation and Pathology of Rheumatoid Arthritis"), that even the flexor tendons may become displaced into the grooves between the heads of the metatarsals instead of passing over them.

The interossei being rendered useless in this way probably waste to a certain extent, accounting for their supposed paralysis, which is really an effect of the changes in the foot, and not the cause of them.

The characteristic tilting of the toes, and especially of the big toe when attempts are made to extend the foot, is due to the action of the extensors, no longer opposed, but rather aided by the interossei, while extension of the foot is resisted by the tendo Achillis.

Though the extensors are shortened to a certain extent,

there is no evidence that they have any primary action in the production of the deformity under consideration ; their range of movement is good, though the effect produced is small.

It is obvious, on comparing Figs. 2 and 4, that the condition of the toes will be more conspicuous in talipes equinus with pes cavus than in talipes equinus alone ; the extreme condition is seen in Fig. 3. To sum up, the deformity of the toes is due primarily to the foot being in the equine position, and secondarily to the displacement of the interossei and contraction of the extensor muscles.

The weight of the body being transmitted through the heads of the metatarsals causes, as a rule, considerable discomfort, but in several cases I have seen the patients did not suffer much pain until the curving of the plantar arch, stretching of ligaments, alteration in shape of bones, &c., were taking place ; then with these were associated corns beneath the heads of metatarsals and over the first phalangeal joints, with bursæ on the dorsum.

It follows from what has been said that there is an approximation of the bases of the toes to the heel, consequently the plantar fascia contracts to accommodate itself, this being again a result, not a cause of the deformity.

The contraction of the tibial muscles, anterior and posterior, that is sometimes seen is either a shortening due to approximation of attachments, or is a true shortening, the result of fibroid changes after infantile paralysis ; in the latter case there will of necessity be a more or less marked varus added to the equinus or equino-cavus. A similar statement will apply to the peronei muscles. That the deformity might be due to a combined overaction of the tibial and peronei muscles is negatived by the occurrence of pes cavus in those only who walk with the affected foot.

My contention is, then, that pes cavus is a secondary deformity, resulting from the transmission of the weight of the body to the ground through a foot in the position of talipes equinus. It is a secondary deformity in that it

is consequent on talipes equinus or equino-varus, and in slight cases it is compensatory. This compensatory arrangement is, however, limited.

The following statistics, taken from the 'Guy's Hospital Reports' for the last five years, well bear out my conclusions :

Of 53 cases of talipes equinus or equino-varus with or without pes cavus, 15 were congenital, 38 were acquired.

A. *Congenital Cases.*

Eleven cases of talipes equino-varus below three years of age ; 3 cases of talipes equino-varus with pes cavus, aged seven, twelve, thirteen years ; one case of talipes equino-varus without pes cavus, aged seven years.

In the last case, placed separately as an apparent exception, the presence of equinus was extremely doubtful, so that this apparent exception is really confirmatory.

B. *Acquired Cases.*

Four cases of talipes equinus with or without varus below four years of age ; 1 case of *very extreme* talipes equinus, no pes cavus, aged seven years ; 2 cases of pes cavus, in one of which it is definitely stated that power of extension of foot was absent ; 16 cases of talipes equino-varus with pes cavus, the ages of which were—four and a half years, 2 ; six years, 2 ; seven years, 1 ; eight years, 3 ; twelve years, 2 ; fifteen years, 2 ; after fifteen years, 4.

One child, aged seven, with talipes equinus and slight varus, had no pes cavus ; he had worn a high-heeled boot for some years.

It may be argued, of course, that these figures give no idea of the date when the deformity began, but the condition of pes cavus being a gradual development, such a date cannot be definitely fixed in any case. What is important is that in no case was pes cavus noticed before four and a half years of age, *i. e.* about three years after

first walking, a point strikingly suggestive of an acquired deformity. The preponderance of cases between the ages of five and fifteen years is obviously due to the bones of the tarsus and metatarsus being more mouldable, and capable of better adaptation to altered conditions, in early than in later life.

In the three congenital cases it appeared as though the primary condition was that of talipes equinus, and the cavus developed as an acquired condition after the patient had learnt to walk. Cases of congenital high arch do occur, but in these there is probably no deformity of the toes ; in fact, there is no reason why such should develop in a primary pes cavus, supposing such a condition to exist.

The conclusions justified by the above figures seem to me to be—1. That pes cavus is a secondary deformity engrafted upon talipes equinus with or without varus.

2. That pes cavus is not congenital, although it may follow upon congenital talipes equinus or equino-varus.

3. That it is the direct result of the transmission of the weight of the body to a foot in the position of talipes equinus, and is the result of a compensatory change, tending to bring the heel to the ground.

4. That the changes in the soft parts, and in the position of the toes, are due to alterations in the arrangements of the tarsal and metatarsal bones, *i. e.* are consequent on the deformity.

NOTE.—In the absence of the author there was no discussion on this paper.