PES CAVUS: A CLINICAL STUDY WITH SPECIAL REFERENCE TO ITS ETIOLOGY.

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PES CAVUS has long been recognised as a distinct clinical entity, but its etiology is still a controversial subject and the theories concerning its nature and significance are so numerous as to suggest that none is in itself adequate to explain the clinical facts observed.

Definition.—Pes cavus or hollow claw-foot is a deformity exhibiting three cardinal features (Steindler [11]).

(1) An increase in the height of the longitudinal arch.
(2) A dropping of the anterior arch with plantar flexion of the front of the foot.
(3) A variable amount of dorsal retraction of the toes, the claw-foot deformity proper, with hyperextension of the metatarsophalangeal and flexion of the phalangeal joints.

Although this paper is primarily intended as a detailed record of six cases, it was found that a proper appreciation of the points presented by these could only be attained by the analysis of a larger number. The records of a further series of cases have therefore been investigated; the tabulated results are appended and form the basis for discussion.

An attempt has been made to discover what condition is most frequently responsible for the deformity at different age periods, and whether there is any correlation between clinical and etiological types or a significant difference in sex or age incidence.

ETIOLOGICAL ASPECTS.

In 1889, F. R. Fisher [3] drew attention to the prevalence of a mild degree of pes cavus and to its *association with specific fevers and other acute illness.* He distinguished and described two stages of the deformity, talipes arcuatus (pure cavus) and talipes plantaris, the latter being intermediate between pure and equino-cavus.

In 1927, pes cavus was the subject of discussion at a meeting of the Orthopædic Section of the Royal Society of Medicine.[1]

Referring to the etiology of the condition, Rocyn Jones considered three main types of cavus according to whether it was of postural, paralytic, or traumatic origin. He also expressed the opinion that slight degrees of cavus were a frequent sequel of acute illness, and Gordon Pugh stated that the prevalence of these cases was not sufficiently appreciated.

Sequel to Equinus.—Rocyn Jones traced the development of pes cavus from an initial foot-drop, resulting from a faulty attitude due to pressure of bedclothes and associated with a transitory paresis of the tibialis anterior or extensor digitorum longus. This slight equinus lasted long enough to allow adaptive shortening of the plantar fascia. On recovery from the illness an awkward gait was sometimes observed owing to the slight degree of foot-drop, but as the tone of the muscles improved the symptoms also subsided. No further immediate effects were observed, but later, perhaps after an interval of years, a differential growth rate came into operation, the contracted plantar fascia could no longer keep pace with the development of other stuctures and acted as a "taut tie-band" bringing the pillars of the long arch into apposition and forcing its convexity upwards. A cavus deformity was thus produced and it needed only some added strain or prolonged pressure to induce symptoms. This theory did not account directly for dorsal retraction of the toes, but Naughton Dunn expressed the opinion that weakness of the tibialis anterior and peroneus brevis were compensated by over-action of the extensors of the toes with the result that "dorsal dislocation" of the toes occurred in the effort to clear the foot from the ground in walking.

Rocyn Jones also referred to the suggestion made by C. A. Parker, in 1913,[21] that cavus resulted from *loss of the reciprocal action* which normally exists between the extensors and flexors of the toes.

Percival Mills[10] has recently revived the *analogy to ulnar paralysis* originally suggested by Duchenne as a cause of the deformity. He shows that paralysis of the intrinsic muscles supplied by the lateral plantar nerve should cause a deformity precisely similar to claw-foot, as *main-en-griffe* is produced in the hand.

Steindler,[11] on the other hand, says "the increase in height of the longitudinal arch is due mainly to the *unopposed or insufficiently opposed pull of the short muscles* of the foot which draw the ball of the foot towards the heel"; but the muscles he

specifically refers to are not the group supplied by the lateral plantar nerve. There is general agreement that *paralytic cases* are mainly due to anterior polyomyelitis and spastic paralysis. The former is productive of a very severe degree of deformity, and the latter is often of congenital origin.

Opinions differ as to the frequency of *congenital* cases, and various *developmental abnormalities* have been suggested to account for the condition. Among these may be mentioned arrest of development or delayed medullation of nerve fibres, or incomplete medullation resulting from premature birth; spinal malformation, such as spina bifida occulta, wedge vertebræ, etc., (these are only discovered if X-rays are employed as a routine method of examination); and a differential growth rate which may be under the control of hereditary influences. Among traumatic cases vascular lesions resulting from intra-uterine or birth injury or other conditions have been suggested which might result in an ischæmic contracture, or in destruction of cortical areas.

The *modern shoe* has been held responsible by some authorities, but here again there is little unanimity of opinion. Thus Fraser[9] associates pes cavus with high heels and the "rôle of the professional dancer" among acquired cases in adults, and Dudley Morton[20] also says, "Shoe wearing . . . . has a distinct tendency towards elevating the arch because it eliminates the retarding effect of the foot's natural flexibility. This seems to explain the greater prevalence of higher arches among the members of the white races as compared to those who are not shoe-wearers." Sir Robert Jones,[8] on the other hand, says, "The modern shoe causes crumpling and distortion of the toes and diminishes the power of the toes to spread, the muscles of the foot atrophy, and a condition is brought about which is opposed to the maintenance of the arch without strain." He therefore appears to think that such shoes produce flat-foot rather than pes cavus, and the context of this statement is in reference to flat-foot.

Consideration of Theories Advanced.—The complexity of the problem is evident, and no single theory can be said to accommodate all the facts.

Mills objects to the hypothesis that paralysis of the tibialis anterior can cause claw-foot, because this is a recognised cause of valgus, whereas pes cavus tends to be varoid, and paralysis of this muscle should actually produce flat-foot.

Mills is still more sceptical of the suggestion that claw-foot can follow paresis of all the anterior muscles of the leg as "this is invoked to explain right angled contraction and mild degrees of talipes equinus." He contends that until it can be explained how pes cavus, an entirely different deformity, can be due to a similar cause, this hypothesis is quite untenable.

Since the publication of his paper, Naughton Dunn and Rocyn Jones, respectively, have to some extent provided this explanation, and Fraser[9] attributes pes cavus to secondary contraction of the muscles of the sole and calf, following paresis of the extensors in polyomyelitis which supports this view.

Mills himself was unable to present conclusive evidence that his hypothesis of the analogy to *main-en-griffe*, theoretically unimpeachable, accounted for the deformity in practice. He endeavoured to establish its validity by investigating the electrical reactions of the interossei, using the faradic bath and testing the abductor hallucis also to serve as a control. In a series of 29 cases, 23 gave a normal response, 5 responded weakly, and in only one was no response obtained; the abductor hallucis responded normally in every case. There was thus only slight support for his theory, but he explains the large percentage giving a normal response on the grounds that at the time of examination paresis was no longer present, and he argues that this does not disprove an antecedent paralysis. There was, however, a history of paresis in only 9 out of 52 cases.

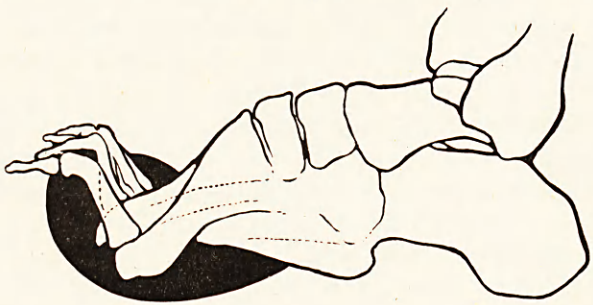
He refers to a case of cavus associated with progressive muscular atrophy which was classified as giving a normal response, and cites this as evidence that the electrical reactions are no criterion of the history of the case. An anomalous result may occur in some cases owing to the fact that normal and degenerate fibres are stimulated coincidently, and a "mixed reaction" is characteristic of all conditions in which the muscle wastes fibre by fibre (Collier and Adie).

A "neurotonic" reaction has also been described by Remak in certain cases of progressive muscular atrophy; it is characterised by an excessive reaction to faradism and galvanism and may be followed by slight tetanus for 10 to 30 secs.[25]

It seems curious that paralysis of the quadratus plantæ (flexor accessorius) and oblique head of the adductor hallucis (both supplied by the lateral plantar nerve) should be associated with an approximation of the anterior and posterior pillars

of the longitudinal arch, for while these are not specifically concerned with the maintenance of the height of the arch they participate in the general shortening of the sole structures in pes cavus, and the origin of the quadratus plantæ is divided in Steindler's operation for correction of the deformity. If these muscles fail to exert normal traction between the ball of the foot and the heel the reverse of an approximation of these two points should result. They might be shortened by atrophy fibrosis, but there is one clinical observation to which no reference seems to have been made, and that is the appearance of the anterior part of the foot in pes cavus, particularly noticeable where comparison can be made with the normal foot of the same individual as in a unilateral case.

There seems to be, if anything, a hypertrophy of the soft



Tracing of radiogram of clawfoot showing outline of soft parts.[12]

parts in addition to the bony prominence of the dropped metatarsal heads and in excess of any thickening of skin or increase in subcutaneous fascia and fat. (Diagram.)

The position occupied by the transverse head of the adductor hallucis (one of the muscles supplied by the lateral plantar nerve) is invariably the site of a fleshy mass projecting at the base of the toes; the remainder of the ball of the foot on the medial side is largely covered by the flexor hallucis brevis (supplied by the medial plantar nerve) but towards the mid-line the oblique head of the adductor also takes part in forming the muscular floor of the sole. If these were atrophic there should be clinical evidence of wasting in the situations indicated, whereas the reverse condition is strikingly noticeable. Dudley Morton,[18] discussing the mechanics of the foot, dismisses the intrinsic muscles very briefly with the statement that in man

they "are apparently undergoing an actual fibrous degeneration"; he regards them as being of slight importance in function and the maintenance of form. They serve, he says, only to increase the spring and resiliency of the foot as a whole, this being one distinction between the anthropoids and man.

If it is a fact that these muscles are actually fibrosed, this might account for the few cases in which a weak response to faradism was obtained, and if this degenerate state becomes more prevalent as a result of civilisation through successive generations, one might anticipate a coincident increase in the incidence of pes cavus, if Percival Mills' solution of the problem is correct.

But according to Dudley Morton the intrinsic muscles have long ceased to bear any important function in the human foot; delicacy and accuracy of movement being unnecessary, these muscles in the feet, unlike their homologues in the hand, have fallen into disuse, their lost function being compensated by ligamentous strength and rigidity.

It is therefore open to question whether any further decrease in their activity could produce so pronounced a deformity as claw-foot, and it would seem that the intrinsic muscles of the foot can no longer be considered strictly comparable to the intrinsic muscles of the hand.

Hence the analogy to *main-en-griffe* must also be subject to criticism.

Present Series.

Classification.—Since etiology affords some explanation of the mechanism producing the deformity, it is to be preferred, and has been adopted, as a basis for classification. It was found that the cases fell into two large groups, according to whether the foundation for the deformity appeared to have been laid in ante- or post-natal life.

The first group includes cases in which a hereditary influence would seem to have been responsible for the condition, and those which are considered to be of congenital origin. The second embraces cases acquired as a result of organic nervous disease, acute illness such as the specific fevers, and also cases which have been termed "postural" and include those of adolescent and compensatory types.

Cases in which the condition was exhibited during the period birth to puberty, in the absence of other etiological factors,

are classified as congenital, and there is evidence that even in adult patients the deformity was sometimes present shortly after birth.

Congenital cases have been subdivided under the headings spastic and non-spastic. The term flaccid, as opposed to spastic, seemed inappropriate as there was no discoverable nervous abnormality at the time of examination, but non-paralytic might be equally incorrect in view of the possibility of antecedent paralysis.

Classification and Analysis of Forty-eight Cases of Pes Cavus.

GROUP I.

Etiology.	No. of Cases.	Percentage.	Sex Incidence. M.	Sex Incidence. F.	Pure Cavus.	+ Equinus.	+ Eq. Varus.	+ Varus.	+ Calcaneus.	Laterality.
Hereditary	3	6·25	2	1	1	1	...	1	...	B 2 U 1 (R 1 L 0)
Congenital	21	43·75	10	11	12	5	2	1	1	B 11 U 10 (R 4 L 3)
(1) Spastic	7	14·3	3	4	4	2	1	...	...	B 4 U 3 (R 2 L 1)
(2) Non-spastic	14	29·16	7	7	8	3	1	1	1	B 7 U 7 (R 2 L 2)
GROUP II.										
Polyomyelitis	9	18·75	6	3	3	4	1	...	1	B 3 U 6 (L 2 L 0)
Specific fevers	6	12·5	3	3	3	2	...	...	...	B 3 U 3 (R 1 L 0)
Postural	9	18·75	7	2	8	...	...	1	...	B 4 U 5 (R 0 L 3)
(1) Adolescent	8	16·5	6	2	6	...	...	2	...	B 4 U 4 (R 0 L 2)
(2) Compensatory	1	2	M		1	...	...	...	...	B 0 U 1 (R 0 L 1)

In last column of table, B = Bilateral. U = Unilateral. (R) = Right, (L) = Left } where side is known.

Group I.

Heredity.—Of the three familial cases, two occurred in males; the female case was characterised by absence of knee-jerks and was suspected of being an example of Friedreich ataxia. Her mother and grandmother had a similar deformity of the feet but are not known to have suffered from any disease of the nervous system.

It is unfortunate that as full family histories are not available the mode of transmission cannot be studied, and it is uncertain whether this is a character conforming to Mendelian

Law. It appeared that in any particular family line the condition was limited to one sex and that transmission was direct, but exceptions would probably be found if previous generations could be traced. It is, of course, impossible on such slight evidence to state that it was sex-linked or sex-limited in the strict sense of those terms. There was no record of any associated features such as spasticity or ataxia which would indicate a genetic relationship to the group of nervous disorders which are recognised to be of hereditary or familial origin.

Congenital Cases.—Cases exhibiting distinctive features, such as spasticity, and which were clearly of congenital origin will not be considered further as their etiology is relatively obvious.

The majority[14] of the cases classified as congenital presented no evidence of any nervous abnormality, and there was nothing in the history sufficient to account for the deformity. In all other respects the child appeared to be normal and in good health, and had not suffered from any severe illness, neither was there any discoverable hereditary element in operation.

Since pes cavus commonly takes some years to develop to the extent of producing symptoms, it is evident that the foundation for the deformity must have been laid very early if not actually in ante-natal life.

Analogy to other Congenital Defects. — It seemed possible that a consideration of other congenital defects might throw some light upon the causation of pes cavus, and the most common of these, talipes equino-varus, appeared most suitable for this purpose. In certain cases pes cavus occurs in association with congenital club-foot (Rugh[17]); and Wilfred Adams,[22] discussing the latter, says, "Though scant attention has been paid to it, flexion (cavus) is an element of this deformity, and needs to be reckoned with," and "The malpositions of the various types of congenital club-foot are no more than exaggerations of the extreme points normally attainable by the movements of the healthy foot"; pes cavus is essentially an illustration of such a malposition. He does not refer to the etiology of the condition, but the question arises, Can a pure cavus deformity be produced by any mechanism which has been suggested to take part in the development of club-foot? In the absence of other etiological factors, talipes equino-varus has been attributed to undue

pressure *in utero*,[4] associated with a deficiency of liquor amnii; and generalised contracture of the lower limbs is believed to be due in some cases to the same cause. In one case in the present series (No. 29) there was, in addition to the cavus deformity, congenital absence of phalanges and bilateral hallux valgus; the former is well known to be associated with oligohydramnios,[6] and the latter might conceivably result from pressure; it is not by any means an integral part of pes cavus, being in fact a very rare accompaniment of that condition. According to Fraser,[9] where hallux valgus is congenital it amounts to a subluxation of the metacarpophalangeal joints.

If the theory of initial foot-drop, with secondary contraction of the plantar fascia, can be accepted as an etiological factor in pes cavus, it seems justifiable to assume that a degree of equino-varus which would escape immediate recognition might develop later into cavus.

In referring to the results of treatment of club-foot, Wilfred Adams[22] says, "Intoeing and traces of equino-cavus have proved the most frequent residue of the deformity"; it may be inferred that cavus persists owing to contraction of the structures of the sole associated with equinus and that such shortening does not yield to manipulation as readily as do the other elements of the deformity. If a very slight degree of equinus was left untreated, being not observed, the ultimate result would be similar to an incompletely corrected equinus initially of more severe degree.

There is also reason to believe that a pure pes cavus deformity even if present at birth would not be detected during infancy. The feet of infants and adults are not strictly comparable, and it seems advisable to review the salient points in this connection before proceeding to a consideration of the mechanism involved, and the clinical features of pes cavus in young children.

Comparison of the Feet of Infants and Adults.

Morphology.—Feldman states[15] that in an infant the longitudinal arch appears to be undeveloped, and an impression of the foot is similar to that of pes planus in an adult. This flattening is, however, more apparent than real, and is due to a well-developed pad of fat on the sole which obliterates the arch. Frozen sections of the feet of infants, and measurements

of the height of the tuberosity of the navicular above the level of the sole in living children, provide confirmation of this statement.

Feldman also quotes the findings of John Dane,[16] who determined the proportion of height of arch to length of foot in infants during the first two years of life.

The figures are as follows:—

Children under 1 year old . .	Proportion height to length	0·301
Children between 1 to 2 years .	„ „	0·218
Adults	„ „	0·270

It is therefore evident that despite its apparent flatness the arch is fully as high in the infant as in the adult foot in proportion to its length.

Function.—Co-ordination of movement also presents distinctive features. In adult life extension of the leg is associated with plantar flexion, and flexion of the leg with dorsiflexion of the foot; in infants the foot normally remains dorsiflexed when the leg is extended.[14]

The transition to the adult type of co-ordination is believed to be regulated by cortical centres which develop after birth, and would seem to be associated with the gradual decrease in the attitude of universal flexion of intra-uterine life. If this is so, it follows that whatever position is adopted *in utero* will tend to persist until counteracted by habit formation under the control and guidance of higher centres. A consideration of the mechanics of development shows that errors of posture may be expected to have far-reaching effects.

Wolff's Law.—"Every change in the form and the function of bones, or of their function alone is followed by a certain definite change in their internal architecture and equally definite secondary alterations in their external conformation in accordance with mathematical laws." It is thus evident that faulty posture or weak musculature occurring in the growth period will result in a bony deformity. The nature of this will depend upon numerous modifying factors and vary according to whether the child walks, or merely "delights in the agitation of its own body." It may be assumed that loss of muscle balance and faulty posture are mutually interdependent.

Cavus in Infancy.—The application of these facts would seem to be as follows:—

(1) An abnormally high arch would not be noticed even if present in an infant.

(2) The second element of pes cavus, dorsal retraction of the toes, might be noticed by an observant parent, though its significance would not be appreciated.

(3) If plantar flexion occurred *in utero* it would persist for a time and allow shortening of the plantar fascia with perpetuation of the deformity.

(4) Loss of muscle balance, due to faulty posture, would be manifested by delay in learning to walk.

The observed facts which support these deductions are:—

(1) An increase in the height of the arch is not noticed even where there was evidence that the condition was present at birth.

(2) Dorsal retraction of the toes may be noticed as in Case 36. "The toes were drawn up" (mother's statement). Case 48. "The toes seemed very fat" (mother's statement).

(3) The deformity is progressive up to a certain point, whereas if due to environmental conditions *in utero* it should regress or disappear when these were removed.

(4) In many cases the child did not attempt to walk until the age of 19 to 20 months. This might obviously be due to other causes, such as rickets, but a history suggestive of this is not always obtained.

Cavus in Childhood.—It may also be inferred that a bony deformity would not develop for some years, and this is in accordance with clinical facts. Even when an increase in height of the arch became noticeable it is doubtful whether any attention would be paid to it. Cavus is merely an exaggeration of a physiological state whose normal limit is undefined.[8] A high arch is considered an asset rather than a defect, and even when symptoms appear their origin is liable to misinterpretation. F. R. Fisher[3] indeed records the fact that flat-foot is sometimes held responsible for pain in cases where its antithesis, claw-foot, is actually present. It is therefore evident that a cavus deformity may be present many years in advance of its recognition; in many cases it is probably exhibited at birth, and may be of congenital origin with greater frequency than has appeared.

Delay in Exhibition of Symptoms. — Case 36 may be quoted as an illustration of the tendency to error in determining

the origin of the condition and the date at which it was exhibited. This case was originally classified as being of adolescent type (postural), and would have remained in that category if an opportunity had not occurred of interrogating the relatives. The patient, aged 24, declared that her symptoms, and therefore in her estimation the deformity also, were of six years' duration, and that prior to that date her feet were perfectly normal. Nothing would shake her belief, but her relatives stated that in infancy her toes were retracted, that she did not walk until 19 months old, and that they had always had difficulty in providing her with well-fitting shoes. She had also worn a support for flat-foot on the assumption that this was the most probable cause of her symptoms.

Case 38 is another example of a congenital case which appeared on superficial investigation to be of "adolescent" type.

Analogy to "Hook Finger."—In Case 48 the position of the fifth toes resembled the congenital contraction of fingers described by Duncan Fitzwilliams,[23] and attributed by him to imperfect development of the anterior ligament of the first interphalangeal joint.

Group II.—Organic Nervous Diseases.

Polyomyelitis. — Apart from the hereditary case referred to as a possible example of Friedreich's ataxia, which is not proven, the only specific nervous disease of etiological importance was polyomyelitis, and it was apparently responsible for 9 of the 24 cases in Group II. It was characterised by the high incidence of compound deformities and by a differential sex ratio of 6 : 3.

Arthur T. Legge,[19] referring to the sequelæ of polyomyelitis, says, "A late deformity that is much more common than is supposed is cavus, occurring in feet without apparent weakness as well as in those with considerable involvement. Between 35 and 40 per cent. of feet either considered normal at the initial examination, or which appear to have become normal after slight involvement develop the cavus deformity." This is of interest, as again it points to the slow development of cavus and the consequent difficulty in determining its true cause or date of onset; and, further, that a very slight or transitory paresis can produce claw-foot. The explanation

of these facts might be either that the intrinsic muscles are alone involved and their paralysis may pass unnoticed (Mills), or that Rocyn Jones is correct in assuming that the plantar fascia plays an important part in the initial stages and can contract to a serious extent on slight provocation, and in a very short time.

Specific Fevers.—These have not figured so prominently as might have been expected, judging from the experience of Fisher, Rocyn Jones, and Gordon Pugh. They are productive of a mild degree of cavus, and it is probable that such cases seldom require operative treatment and therefore are absent from the present series, or the occurrence of fever might not have been noted in recording the history of the case.

In view of the large number of children confined to bed over long periods, it seems that if the causative factor is largely mechanical one might anticipate a still greater prevalence of the condition and the question arises, what factor determines the development of cavus in some cases and not in others? This might be due to the occurrence of *nervous complications.* Various fevers, such as measles, are known to be followed by a peripheral neuritis with subsequent contracture;[5] mumps may also affect the peripheral nerves,[13] and diphtheria is well known to have a specific effect upon nerve tissues and may specifically affect the distal muscle groups. In many of these the neuritis tends to be multiple, and one might expect coincident involvement of the hands, yet these appear less often affected. There must then be some predisposing condition which determines involvement of the feet alone, and here the effect of pressure probably comes into operation. The anterior muscles of the leg are under a mechanical disadvantage in the position naturally adopted in bed, though the intrinsic muscles of the foot are not, and if the latter were affected it would be necessary to postulate the selective action of some toxin upon this small muscle group. The anterior tibial muscles therefore are weakened by stretching and this is well known to render them liable to paresis. It follows also that if the mechanical factor were removed, paresis would be absent, and thus another explanation might be found for the absence of fevers as a causative factor in the present series. In the hospital classes from which these patients were drawn children suffering from such "childish complaints" are not kept in

bed for more than a day or two at most, if nursed at home,* and therefore the effects of pressure and faulty position do not come into operation. It may be that this rapid convalescence prevents foot-drop, and therefore eliminates the subsequent development of cavus, and that in the relatively wealthy it is a more frequent sequel, owing to a longer period in bed. It would be interesting to know from what class of society the cases quoted by Gordon Pugh were drawn.

Possibility of a Latent Congenital Defect.—Yet considering the large shifting population of our fever hospitals, the long periods in bed, and the absence of prophylactic measures such as those suggested by Gordon Pugh,[1] it seems remarkable not that so many cases occur, but that so many do not. Possibly the illness, with its general debility, accentuates a very slight degree of cavus which had previously been latent. The acute specific fevers may have been held responsible on insufficient evidence; clearly their mere occurrence does not prove any etiological relationship, and it may be that some of the cases attributed to them were in reality of congenital origin. The illness may serve to draw attention to the deformity, as in the case of trauma, where closer investigation shows that the injury was so trivial as to warrant exclusion from the list of possible causes.

Postural Cases—Adolescent Type.—There is reason to believe that many of these cases could be traced to a congenital origin, but in the absence of definite proof it was not considered legitimate to include them in that category, though the term "postural" is a confession of failure to discover any explanation of their occurrence, the history being entirely negative.

Shoes.—It is in this age group (14 to 25) that faulty footwear would manifest its effects, and reference has already been made to the results which should theoretically follow the wearing of shoes. In practice, however, there is no support for the assumption that shoes can produce pes cavus though they may play a subsidiary part in accentuation of symptoms.

Occupations.—An explanation might be sought in the more arduous nature of the occupations pursued by men; but this is not valid when it is remembered that women are frequently employed as shop assistants or in domestic service, both of

* Frequently observed in dispensary practice, there is great opposition to keeping the child in bed.

which entail much standing, and this, especially if associated with tight shoes, is pre-eminently conducive to strain.

Trauma.—Similarly trauma might be supposed to affect more particularly the adolescent male, but injury can be seldom proved to be of any etiological importance (Mills).

Congenital Origin.—As in the congential groups the sex ratio is equality, it might seem inconsistent to attribute the "postural" group, with its high male incidence, to a similar cause. But Mills observed an earlier onset among females, and it would seem that in the present series also sex was a factor determining the exhibition of symptoms, perhaps through the medium of shoes.

In the congenital group the average age at which treatment was necessary was 12 years 6 months for boys, and 11 for girls. In the adolescent group the average age of the eight male patients was 19 and (excluding the woman of 78) there was only one female and her symptoms appeared soon after she began work, at the age of 14. The average age at which symptoms necessitated treatment was 15 for both sexes, if the series is considered as a whole.

It has already been noted that the deformity and its symptoms are not coincident in their development (Case 36), and it may be inferred that the former appears at a similar age in boys and girls, but that sex is a determining factor where onset of symptoms is concerned. Thus a congenital origin is rather favoured than disproved.

Sex Incidence.—In Percival Mills' series of 99 cases, half were unilateral without special incidence on the right or left, the average age at which symptoms appeared was 14, which gave little time for the deformity to develop, and the sex ratio appeared to present conclusive evidence against shoes being an etiological factor, 54 of the 90 cases occurring in males.

Mills refers to his entire series; in the present series reference will be made to the sex incidence for the adolescent age group (average 18 years) alone, as its significance in this connection is greater than the ratio for the series as a whole. Of the eight cases occurring after the age of 14, and without any obvious cause, six were males, and excluding cases due to polyomyelitis this was the only group in which the sex ratio did not approach equality. One of the two female cases should be discounted, as it was a woman of 78 (a fracture case) and therefore quite exceptional. The cavus deformity was marked,

but she had no symptoms and was proud of her "high instep" which she had had since she was a girl. This case is not included in estimating age averages, as it would obviously yield a fallacious result.

Laterality.—One or both feet suffered with equal frequency in the present series if considered as a whole, but the group incidence shows significant variation. Of the three hereditary cases two were bilateral, and this one might expect.

It is of interest to compare the congenital and adolescent group with the distribution in club-foot. In a series of 125 cases,[4] both feet were affected in 62 and one in 63, and in unilateral cases the left was involved twice as often as the right. In the adolescent group the distribution was similar to this in all respects; in the congenital group the incidence as regards unilateral and bilateral involvement was the same, but (where the side was known) the incidence on right and left feet was equal.

The fever and polyomyelitis groups may also be compared. In the former one or both feet were equally often involved; in the latter one foot was affected twice as often as were both. Since in polyomelitis there is an aggregation of causative factors, a bilateral deformity might be expected, and this restricted involvement may be a significant indication of the effects produced by pressure. Polyomyelitis is the one condition where prophylaxis by splints and cradles is a routine method of treatment, and this may possibly explain the limitation to one foot.

Mills considered his series of 99 cases as a whole; 42 were unilateral involving equally right or left feet, while 57 were bilateral (not stated in 6) so that the distribution was approximately similar in both series, but the failure to record group incidence restricts the significance of distribution.

Compound Deformities.—No attempt has been made to limit this discussion to cases of pure pes cavus, because it seems to be generally recognised that the more severe degrees exhibit some additional element.

F. R. Fisher[3] described advanced cases as talipes plantaris, a condition intermediate between pure and equino-cavus, and Sir Robert Jones[2] distinguishes between the 4th and 5th stages of the deformity according to whether varus or equinus respectively are also present.

According to many authorities, among whom may be mentioned W. A. Cochrane, Percival Mills, and Rocyn Jones, there is seldom real shortening of the tendo Achillis, and the dropping of the ball of the foot at the mid-tarsal joint only simulates equinus; it is in fact the plantaris type described by Fisher. In many cases correction of the cavus deformity by Steindler's operation removes the equinus element without any interference with the tendo Achillis, whose integrity is necessary as it serves as a fixed point for manipulation.[7] This illustrates the fact that shortening is often more apparent than real, and that the term equinus should be used with caution.

In these records there is no reason to doubt that true equinus was present where stated, and the incidence (15 out of 48 cases) is somewhat similar to that in a series referred to by Percival Mills, where 17 cases showed definite shortening of the tendo Achillis out of a total of 64.

In Mills' series the cases exhibiting equinus were invariably old-standing pes cavus of severe degree, and the average age of such patients was also greater, being 22½ as compared with 14 for the series as a whole. In the present series the average age of patients with equinus was 13 as compared with 15 years 8 months for cases of pure cavus, therefore in these equinus does not seem to have been associated with chronicity.

In the polyomyelitis group more than half the cases showed equinus, and it was present in slightly less than half of the spastic congenital group, *i.e.* it was characteristic of cavus of paralytic origin. One-third of the non-spastic congenital and fever cases were complicated by equinus, and it was absent from what may be termed the "delayed congenital" or adolescent group.

Varus and calcaneus occurred so infrequently that no special reference is necessary, and the exact incidence of all deformities will be seen in the tabulated results.

Relation of Equinus to Cavus. — Equinus might be primary, secondary, or coincident with the development of cavus, and its relation might be significant in connection with etiology and in view of the hypothesis of Rocyn Jones.

Secondary Equinus.—It is therefore necessary to consider what static alterations might result from pes cavus and lead to the production of secondary deformity, as in any chronic case effects of abnormal strain and loss of balance would be seen. For example, there is no doubt that patients affected with

painful callosities on the ball of the foot seek to ease their discomfort by transposition of weight on to sound areas, and if the head of the first metatarsal is the point of maximum tenderness the foot will tend to assume a varus position in order to relieve pain in this situation. Similarly in a unilateral case, if weight is taken off the foot as a whole it will be liable to be held dependent, which might in time lead to adaptive shortening of the tendo Achillis.

Primary Equinus.—If, on the other hand, foot-drop is indeed a preliminary step towards pes cavus, slight equinus might persist, and it must then be present in the early stage of the deformity. This is known to be the case in a certain type of claw-foot[7] which is associated with a short tendo Achillis in its initial stages. The shortening of the tendon may be the primary defect, or might itself be secondary and adaptive following a postural equinus. In either case its relation to cavus is clearly that of cause rather than effect.

Mills' observation that equinus occurred in chronic cases and in older patients is in favour of it being a secondary deformity. Observations on the present series are opposed to this view and suggest that it is a primary or coincident defect. The average age for cases of pure cavus here is high because they include the whole of the adolescent age group, while polyomyelitis occurred in the youngest patients, presented the largest number complicated by equinus, and thus reduced the average age exhibiting the deformity. Equinus must therefore be regarded as a criterion of severity, not chronicity; it is most common in cases of paralytic origin, and in these must be considered to represent the persistence of a primary defect, which may or may not have preceded the development of cavus.

If not primary to cavus, it was probably coincident in its time relation, and it would in that case determine a progressive increase in the cavus element, which may explain the severe degree of deformity which cases of paralytic origin assume. Therefore whether equinus is primary to cavus or of simultaneous origin, it appears to be a factor of importance in the production of advanced claw-foot; it must be assumed to exert its influence through contraction of the plantar fascia, and to this extent there is support for the theory of Rocyn Jones. Corroborative evidence is also found in the fact that early stages of the deformity, of whatever origin, exhibit some degree of shortening of the plantar structures.[2, 12]

Mere speculation is unprofitable, and these theories should be put to the test of experiment. Observations upon the feet of infants and young children might also throw light upon the etiology of pes cavus, determine its true age of onset, and its relation to other defects. This would incidentally provide the possibility of correction while the deformity was still amenable to manipulative treatment alone.

It is admitted that 48 is too small a number from which to draw final conclusions, and that any critical inference must be deferred until further data is available. It is notoriously dangerous to argue from insufficient evidence. The results recorded here may, however, represent a true average such as analysis of a larger number of cases would yield, for the figures as regards sex and age incidence, laterality, and compound deformities are in close agreement with the findings of Percival Mills in a series of 99. The facts recorded may therefore be of value; interpretation must be tentative until its validity is further established or disproved.

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Summary.—(1) Pes cavus is probably of congenital origin in cases of obscure causation, and a late onset of symptoms does not disprove the theory that it is a congenital defect.

(2) The age at which symptoms are exhibited is largely determined by sex; females require treatment earlier than males, and this may be due to shoes.

(3) There is no evidence that shoes can produce pes cavus in a previously normal foot.

(4) Hereditary cases appear to be limited to one sex in a particular family line and transmission is direct.

(5) Fevers and other acute illnesses do not produce a deformity which requires operative interference, and this probably accounts for the small number of cases in the present series.

(6) Polyomyelitis is responsible for the majority of acquired cases, and for a very severe deformity with a high incidence of associated defects.

(7) The sex ratio approaches equality in all but two groups. In the polyomyelitis group males were affected most frequently

in the ratio of 6:3, and the adolescent age group also shows a high male incidence, but the reason is found under (2).

(8) The distribution of the deformity in congenital cases is comparable to that of club-foot, and the adolescent age group is similar in all respects.

Polyomyelitis accounted for more unilateral than bilateral cases in the ratio of 6:3. In the fever group one or both feet were affected equally often. Of three hereditary cases two were bilateral.

(9) Equinus is the most common additional deformity; it is a criterion of severity, not chronicity, and is characteristic of a paralytic origin. It either precedes cavus or is coincident in its time relation.

(10) Trauma is an uncommon cause of the deformity.

APPENDIX

Case Histories.

Case I.—D. M., female, aged 24 (No. 36 in series). The patient had been employed as a saleswoman for eight years, and for six years had suffered from pain referred to the anterior arch and inner border of both feet, with œdema of the ankles. Examination showed distinct cavus, the metatarsal heads were prominent in the sole and not replaceable by pressure, and there was dorsal retraction of the toes of the left foot. There was no cardiac abnormality. Apart from the long hours of standing which her work entailed, there appeared to be no reason for this abnormality; her shoes did not seem to be at fault, but her mother stated that the latter were never comfortable until she had "worn a nest in them," the site indicated corresponding to the dropped metatarsal heads, and this difficulty had been experienced since childhood, although no other symptoms were noticed at the time. Treatment consisted of subcutaneous division of the plantar fascia with tenotomy of the long extensors of the toes in the left foot, followed by remedial exercises.

The symptoms recurred slightly on returning to work, but were relieved by wearing a metatarsal bar.

The final result was satisfactory.

Case II.—G. B., male, aged 38 (No. 39 in series). The patient was an engineer, and for ten years had suffered from dull aching pain referred to the anterior arch and muscles of the left foot and leg. He

also complained of burning pain due to corns on the sole, and occasional attacks of severe cramp. The left foot was inclined to be cold and cyanosed. Examination showed advanced cavus with limitation of dorsiflexion at the ankle and wasting of the muscles of the leg. The patient had a slightly unsteady gait and his articulation was indistinct, but there was no other abnormality of the nervous system, and his reflexes were normal. It therefore appeared unjustifiable to classify this case as of nervous origin although the ataxic symptoms referred to suggested the possibility of such a cause; the family history was negative. Steindler's operation was performed, followed by massage and exercises. Correction of the deformity was incomplete but the functional result was entirely satisfactory.

Case III.—V. H., female, aged 8 (No. 48 in series). This patient presented one curious feature in acute dorsiflexion of the little toe in each foot, both feet showing in addition an early degree of cavus. The condition resembled the congenital "hook finger" described by Duncan Fitzwilliams, and the patient's mother stated that in infancy the child's toes looked "fat" compared with the toes of the other children, and that later the patient was unable to run about as she developed "walking skin," *i.e.*, a tendency to form blisters on the sole over the metatarsal heads. The condition appeared therefore to be of congenital origin, although no marked disability was evident until the child was old enough to lead an active life.

Treatment was satisfactory and consisted of division of the extensors of the toes and stretching of the structures of the sole.

Case IV.—J. G. K., male, aged 26 (No. 38 in series), had suffered from pain in the left foot since early boyhood. When working at the pithead at the age of fourteen he became totally incapacitated and was under treatment for some weeks, with temporary improvement. During the war a blow on the foot caused a recurrence of symptoms of less severity, and afterwards he was employed as a motor-bus driver; but this occupation proved unsuitable owing to the strain on his foot using the clutch.

He was admitted to the Royal Infirmary and Steindler's operation was carried out, followed by the usual after-treatment. After discharge he immediately returned to work, and ten weeks later he was still entirely free from pain.

In view of the early occurrence of symptoms it seemed probable that this case was of congenital origin, and such a view is supported by the mother's statement that from the age of five it was difficult to provide the patient with comfortable shoes, as in the left foot the interphalangeal joint of the great toe was invariably blistered, and it may be assumed that other structural defects were present at the same time.

No. in Series.	Age.	Sex.	Age of Onset.	Etiology.	Coincident Deformities.	Laterality.	Extracts from History.
1	25	M	10	Polyomyelitis	Equino-varus	Bilateral	.....
2	18	M	Youth	Adolescent	...	,,	Worse recently. Some deformity for years.
3	12	M	Birth	Congenital	...	,,	No spina bifida. Worse recently.
4	27	F	$2\frac{6}{12}$	Polyomyelitis	Equinus	Unilateral	Operation for equinus at 5. Arm of same side affected.
5	20	M	Birth	Congenital	,,	Unilateral (R)	No spina bifida. Worse for three years.
6	13	M	$1\frac{6}{12}$	Fevers	...	Bilateral ?	Pneumonia at 6 months. In bed two months. First noticed scarlatina and diphtheria later. Did not walk until 2 years 6 months.
7	21	M	Childhood	Congenital	...	Bilateral	Worse recently.
8	20	M	Youth	Adolescent	...	,,	Worse two years ago.
9	12	F	12	Cong. Spastic	Equinus	Unilateral (R)	Duration of symptoms two weeks. New shoes four weeks previously.
10	14	M	Birth	Familial	...	,, ,,	Unusual epiphyses, especially base of fifth metatarsal. Mother's brother and cousin similar deformity.
11	9	M	2	Cong. Spastic	...	Bilateral	.....
12	3	M	Recent	Congenital	Equinus	Unilateral	History of fall, origin obscure.
13	16	M	Youth	Adolescent	...	?	.....
14	25	M	15	,,	...	Bilateral	.....
15	21	F	Childhood	Cong. Spastic	...	,,	.....
16	14	M	,,	,, ,,	...	,,	.....
17	12	F	,,	Congenital	Equinus	,,	.....
18	13	F	2	Polyomyelitis	,,	Unilateral (R)	.....
19	9	M	1	,,	...	?	.....
20	15	M	Recent	Adolescent	...	Unilateral (L)	.....
21	15	M	$\frac{11}{12}$	Polyomyelitis	Calcaneus	Unilateral	.....
22	25	F	15	Scarlatina	Equinus	,,	.....
23	11	M	Infancy	Polyomyelitis	,,	,,	.....
24	16	F	Recent	Congenital	...	,,	Slight mental deficiency.
25	14	M	$\frac{6}{12}$	Polyomyelitis	...	Bilateral	.....
26	21	M	Childhood	Fevers	Equinus	Unilateral (R)	.....
27	16	M	,,	Polyomyelitis	...	,, ,,	.....

28	13	F	2	*Congenital*	*Calcaneus*	*Unilateral (R)*	*History of encephalitis lethargica, but right leg had always been short and right arm also.*
29	12	F	Childhood	„	Bilateral hallux valgus	Bilateral	History of "shock" with paralysis at 3, affecting one side only. Congenital absence of phalanges.
30	8	F	6	Diphtheria	...	Unilateral	.....
31	10	F	Recent	Cong. Spastic	Slight equinus	Unilateral (L)	.....
32	$5\frac{5}{12}$	M	„	„ „	...	Bilateral	History of fall. Swelling (bursa) noticed three weeks.
33	5	M	„	Congenital	Varus	„	Congenital varus deformity at metatarsal joint.
34	7	F	5	„	Slight equino-varus	Unilateral (L)	Noticed that child drags left foot.
35	6	M	Birth	Familial	Varus genu valgum	Bilateral	Not walking properly for one year. Some adduction. Long type of foot. Worst in morning.
36	24	F	18	Congenital	...	„	Worn flat-foot support six years with no effect. Toes dorsiflexed in infancy. Did not walk until 1 year 7 months.
37	7	M	Childhood	Compensatory	...	Unilateral (L)	Right equino-varus result of polyomyelitis in infancy.
38	26	M	14	Congenital	...	„ „	Tendency to blisters on inter-phalangeal joint of great toe since age of 5.
39	38	M	28	Adolescent ?	Slight varus	„ „	Speech defect.
40	17	F	15	Polyomyelitis	Equinus	Bilateral	Mental deficiency.
41	23	F	Youth	Adolescence	Varus	„	Below average intelligence.
42	26	F	12	Diphtheria	...	„	Weakening of peronei. Pain recently in anterior arch.
43	78	F	?	Adolescent ?	...	Unilateral	Marked cavus deformity but no symptoms. Deformity had been present ever since patient could remember.
44	26	F	Childhood	Familial	Equinus unilateral	Bilateral	Mother and grandmother similar. Knee-jerks absent. ? Friedreich's ataxia.
45	27	M	„	Fevers	...	„	Both great toes shorter than first toes.
46	7	F	$2\frac{6}{12}$	Cong. Spastic	Equino-varus	Unilateral (R)	History of foot being twisted at 2 years 6 months. Right leg under-developed. No response to electrical stimulation of intrinsic muscles of foot.
47	21	M	Childhood	? Meningitis. Congenital	Metatarsal. Flat-foot	...	Meningitis at 10. Foot always smaller (? since 10). Worse last two years. Occupation entails standing.
48	8	F	7	Congenital	...	Bilateral	Extreme dorsal retraction of little toe, especially on left side. Remaining toes practically normal.

Case V.—R. C., male, aged 27 (No 45 in series), a baker, complained of pain in both feet, most severe in the right, and hyperidrosis. His occupation entailed much standing, and the symptoms were worst at the end of the day.

Examination showed increase in height of the longitudinal and transverse arches, with retraction of the toes. In both feet the great toe was shorter than the second toe, the interphalangeal joint of the right toe showed callosities, and on the left a bursa had formed. A slight fullness could be seen over the *extensor digitorum brevis.*

The patient had had a high instep since childhood. He gave a history of measles, chicken pox, scarlet fever, and diphtheria, and in view of the suggestion that the specific fevers may lead to the development of pes cavus, it is possible that they may have been an etiological factor in this case. Steindler's operation was performed on the right foot, and the result was entirely successful as regards both structure and function.

Case VI.—M. W., female, aged 7 (No. 46 in series). This patient gave a history of injury to the right foot, resulting from an accident in a go-cart at the age of two years six months. Her mother noticed that the foot was deformed and took her to hospital, where the foot and leg were put in plaster extending to the waist. Radiographs were negative. The child appeared strong and healthy but small for her age; she walked with a limp but there was no pain or tenderness.

The right foot was in a position of equino-varus with some degree of cavus. The knee-jerks were increased. No electrical response could be obtained with either current from the small muscles of the foot; the leg muscles showed no abnormality. Steindler's operation was performed for correction of the cavus deformity, with transplantation of the tendon of the *extensor hallucis longus* into the *extensor hallucis brevis* and the head of the first metatarsal. It appeared probable that the injury only served to direct attention to the deformity. Since the spasticity was bilateral it could not be due to trauma, and as a pronounced deformity was present at the age of two years six months it may be assumed to have been a congenital defect.

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