from this, there would not appear to be any considerable difficulty, for with reasonable care the heart and lungs are not likely to suffer from ill effects. On general grounds one would expect that such a method ought to produce more satisfactory results than any of those hitherto employed, since the growth with which we are dealing is certainly radio-sensitive, and the only real danger is that by too energetic a dose we may produce sloughing of the tissues and perforation. Combination with internal radiation from a tube or from seeds would seem to be a rational method, but so far it has not been developed.

Deep X Rays

Results of great interest have recently been obtained by Levett using deep x rays, the radiation consisting of very hard rays and being limited to a narrow field, including seven inches of the oesophageal wall. It is still too early to speak with any certainty of the results secured, but in a few cases at least it would seem that complete healing had been obtained without secondary stenosis. Hitherto the disadvantage of x -ray treatment in these cases has been the intensely depressing effect upon the patient, due apparently to the effects of the x rays upon the surrounding structures, and perhaps to the absorption of products so formed. So severe have been these effects that radiologists of the brilliant achievement of Coutard have entirely abandoned the method. If, however, these secondary effects could be avoided by skilful adjustment of the apparatus, the method would appear to have definite possibilities, and it is certainly one which should be explored to the full.

Another method which we are at present ourselves investigating is the application of radon to the outer surface of the oesophagus after exposure by transthoracic exploration. It is a very remarkable fact that even in elderly subjects the lower half of the oesophagus can be fully exposed by the transthoracic route apparently without risk and with only trivial inconvenience to the patient, far less in fact than is associated with an ordinary laparotomy. Theoretically, if a growth of the oesophagus could be surrounded by a group of radon seeds there is little doubt that the growth would entirely disappear and that healing of the mucosa would occur. The mechanical problems involved are, however, difficult to solve, and in spite of a few encouraging examples we can still only regard the method as in the experimental stage.

Conclusions

It will be seen, then, that for the present we regard the relief of dysphagia as the one object to aim at in the treatment of carcinoma of the oesophagus, and we consider the introduction of a spiral tube as the method most likely to achieve this in practice. Our personal experience of the method now extends over some fifteen years, and includes upwards of 300 cases, whilst the method is in general use by many other surgeons. We consider, however, that every attempt should be made to develop the method of radiation both by radium and by x rays, since although both of these are still in the experimental stage they are probably the only methods to which we can look for any real prospect of curing the disease.

ADOLESCENT AND SENILE KYPHOSIS*

BY

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(With Special Plate)

It is about time that opportunity was given for the ventilation of ideas upon the difficult and puzzling subject of adolescent kyphosis. Though the literature is now abundant, most of the work seems to have been done by American, French, German, and Italian authors, and very little by Englishmen. It was not until Beadle¹ and Ross-Smith² published their papers in 1931 on the intervertebral disk that much thought was given to this structure in Great Britain, or to the possible association of its pathological conditions with adolescent kyphosis. It seems strange that this should be so, for it cannot be doubted that the condition has long been recognized here by orthopaedic surgeons and those working in institutions for surgical tuberculosis. In fact, one of its chief claims to recognition is that adolescent kyphosis, on account of its occasional combination of pain, deformity, and peculiar x -ray appearances, constitutes one of the most important differential diagnoses from spinal caries. Sorrell³ says that 25 to 30 per cent. of cases sent to his hospital with a diagnosis of spinal caries turn out to be cases of adolescent kyphosis.

Clinical Picture

Obviously, unless one has worked on this comparatively rare condition for a long time, it is difficult to collect a sufficient number of cases to give any valuable statistics on the relative frequency of any particular type of onset. I shall therefore content myself by merely enumerating the varieties.

Adolescent kyphosis starts between the ages of 12 and 17, normally a period of active growth, and is said to be more common in boys than in girls. The deformity may become exceedingly unsightly (Fig. A), but the active process tends to cure itself spontaneously in the course of eighteen months. If treatment is carried out early the deformity may even be lessened, but it is doubtful if it can ever be entirely corrected. In my small group of cases, and from a perusal of the literature, I think I can detect five different classes.

1

The onset is insidious. Kyphosis gradually develops, but the patient himself is unaware of it. He is usually brought up for advice by his parents, who are alarmed at the deformity. There is, however, no pain—at most a sense of fatigue at the end of the day or after exercise, but often not even that. There may be no history of trauma, and he appears to be in perfectly good health and of normal development. The posture is poor on account of the round back, but the musculature is good and there is no spasm. The kyphosis, however, cannot be corrected either actively or passively, and there is often a certain amount of rotation of the vertebrae. The hamstring muscles may be short.

2

In this group the onset is also insidious, but the patient belongs structurally to an altogether different type. The child is tall and lanky, and there may be a history of debilitating illnesses in childhood following rapidly one upon another. The musculature is inadequate, and the posture is very bad. He complains of backache, which appears, however, to be due to fatigue. In him, too, the movements of the spine are not restricted by spasm, but the hamstring muscles are markedly contracted. He belongs, in fact, to the type of child who acquires postural deformities, but in whom the kyphosis becomes fixed earlier than usual.

3

In this class are included those cases in which the onset is fairly sudden. There may be a history of a fall a month or so previously, or a period of exceptional activity at work or at play. Scheuerman,⁴ who first drew attention to the condition in 1920, was so impressed by this that he called it

* Read in opening a discussion in the Section of Orthopaedics at the Annual Meeting of the British Medical Association, Bournemouth, 1934. The author's section on Senile Kyphosis has been omitted for reasons of space.

"apprentice kyphosis." Pain is a very definite feature, and there is said to be sometimes a rise of temperature. The pain is never very acute, but it is sufficiently severe for the patient to seek advice on account of it. The movements of the back are restricted by spasm, and the spinous processes are said to be tender on pressure. The symptoms disappear with rest, and the kyphosis may even improve a little.

4

In this type the patient is definitely overgrown. One of my cases, a boy of 15, was 6 ft. 1 in. These cases, however, differ from those in Class 2, inasmuch as their musculature is not so poor and they exhibit other signs of endocrine disturbance. Albanesi has collected a number of cases in which changes are seen in the sella turcica and also in other parts of the skeleton, suggestive of an endocrine imbalance.

5

Some cases have been described as coming on rapidly after an acute pneumonia. Albanesi⁵ refers to this, and Edelstein, who has written on the subject, has told me that he quotes one such case.

Although the mode of onset and the type of patient may be varied, there are certain clinical features common to all classes.

1. The kyphosis is always round and never angular.
2. The kyphosis is always in the lower dorsal region.
3. The x-ray appearances are constant and characteristic.
4. The hamstring muscles are, I believe, usually short.

Scheuerman and the French school lay great emphasis upon pain in these cases. In fact, they have termed the condition "painful kyphosis of adolescence." I do not think that this is by any means a constant feature, and if we were to restrict ourselves in this discussion to those cases alone which have pain I feel sure that we should overlook a lot of important details.

X-Ray Appearances

In a fully developed case, where the active process has ceased, the vertebrae from the seventh dorsal to the first lumbar (often fewer, but rarely more) are wedge-shaped. The intervertebral disks are narrowed, and the vertebral borders, above and below, are sclerosed with punched-out areas in them, looking moth-eaten. In the early stages the point that Buchmann⁶ lays great stress upon is that the adjacent vertebral borders are indistinct and irregular, and even the whole vertebral body may become hazy. The epiphyseal points may be delayed in their appearance, and when they do appear they are denser than normal. As regression occurs the definition of the vertebral bodies becomes clearer and the epiphyseal plaques seem to be fragmented and dense. It is only in the later stages, when the whole of the plaque has become sclerosed, that the typical punched-out conformation can be seen.

Aetiological Factors

Whitman,⁷ in discussing coxa vara, says that the condition is due to a discrepancy between strain and stress on the one hand and the capacity of the bone to bear it on the other, and it will be useful in reviewing the theories

of aetiology of adolescent kyphosis to divide them into these two main headings.

Factor of Weight-bearing Capacity

The conditions which diminish the capacity of the bone to bear weight are: (a) circulatory; (b) infective; (c) endocrine or metabolic disturbance; (d) physiological weakness; (e) hernia of the intervertebral disk (Schmorl's theory). I will now discuss these seriatim.

Circulatory

Owing to the fact that specimens of Perthes's disease show that the bone nucleus has undergone a necrosis, some authors seek to explain, not only Perthes's disease, but most of the other osteochondritides and epiphysites as being due to embolism. So far as the back is concerned, however, it is difficult to see how emboli could reach simultaneously a limited number of vertebrae over a certain area of the spine at a certain age. It appears to me to be a very far-fetched theory.

Infective

Despite the fact that it is exceptional for organisms to be found in any of these epiphyseal conditions, the infective theory still has a large number of supporters. Those who favour this view do so because they think that it best explains the radiographic appearances, but I find it difficult to believe that infection which is sufficient to cause destruction of bone can occur without pain or occasionally giving rise to abscess formation. Apart from the jaw, I do not know of any other situation where there is chronic infection in bone without pain. It is upon this question of pain where my experience, as far as it goes, differs from that of other authors. There are some cases of adolescent kyphosis where pain is a prominent symptom and even a rise of temperature has been recorded; but these are few, and in most cases where pain exists it is not of an inflammatory nature.

If infection does play a part at all, it must be of the very mild and transient kind which gives rise to thromboses, similar to spontaneous thromboses elsewhere in the body. Such disturbances of the circulation weaken the bone, and any subsequent changes are of a secondary nature owing to the peculiar mechanical arrangements that prevail in the intervertebral disk, and not to the destructive action of the organism itself. This infection would have to be of a very special kind, having an affinity for the blood vessels of a limited number of vertebrae, over a certain area of the spine, at a particular age! But what explains those cases of adolescent kyphosis that come on acutely during the course of a pneumonia?

Thanks to the writings of Watson Jones, spontaneous dislocation of the atlas, associated with an acute or chronic pharyngitis, is now a well-established, though rare, clinical entity. The hyperaemia produced by the pharyngitis causes decalcification of the bone and slackening of the ligaments, permitting a dislocation; but it must be noted that in this region no intervertebral disks exist. I do not think it is straining the imagination too far to presume that a similar condition might exist lower down the spine.

FIG. A.

FIG. B.—To show deformity and short hamstrings.

Supposing, during the course of a bronchopneumonia, the mediastinal glands were to become inflamed (as they undoubtedly do): this might produce decalcification of the vertebral bodies, and any minor traumata during the course of nursing, or maybe a paroxysm of coughing, might result in subchondral fractures. A dislocation, of course, could not arise because of the presence of the intervertebral disks. One of my colleagues has promised to x-ray the dorsal spine of every child convalescent from bronchopneumonia, and in the course of time I confidently anticipate to be able to report that the sequence of events I have visualized does occasionally occur. To sum up then: infection, in the sense of invasion by organisms, though it may be responsible for some cases, is probably a very rare cause.

Endocrine and Metabolic Disturbances

Late rickets has, at one time or another, been held responsible for this and all other epiphysites. Several cases were reported in Vienna during the famine stages of the war, but in these the disturbances were more widespread, and it can be assumed not to be an important factor in normal times.

I have already mentioned Albanesi's researches, and I believe his article to be an important contribution to the literature, but I feel inclined to take the view that Whitman takes in regard to coxa vara: which is that where coxa vara coexists with Fröhlich's syndrome the cause of the slipping is more likely to be due to the abnormal weight the epiphyses have to carry than to the fact that the endocrine disturbances affect the quality of the bone or its growth. One of the reasons which I think support this view is that only those epiphyses which have to withstand a shearing strain, such as the hip, the knee, and the dorsal vertebrae, appear to be affected. There are no changes in the ankle-joint, for instance, in Fröhlich's syndrome, in spite of the fact that the weight borne by the ankle-joint is greater than that borne by any of the other joints: this is undoubtedly due to movements of the subastragaloid joint, which protects the lower tibial epiphyses from a shearing strain. In connexion with this, it is interesting to note that Buchmann alludes to a case where adolescent kyphosis coexisted with changes in the epiphysis of the iliac crest. At first sight this might appear to be a case of multiple epiphyseal lesions of the endocrine or metabolic variety, but when one reflects that many powerful ligaments are attached to the posterior part of the iliac crest, in order to control the rotatory movements of the sacrum, the occasional combination of what one might call a "pulled" epiphysis of the ilium with adolescent kyphosis supports rather than refutes the strain theory.

Physiological Weakness

Murk Jansen⁸ has enunciated the theory of the vulnerability of rapidly growing young cells, and it would seem from this that during periods of rapid growth the bones are weaker. Generally speaking, there are two periods in which growth is particularly active—between 3 and 6, and between 12 and 17 years. During these two periods there may be said to exist a state of physiological weakness of the bones. Supposing that during either of these stages the back was subjected to undue strain or varying degrees of trauma, disturbances of growth might be expected to arise. This point will be referred to again later, in discussing short hamstring muscles.

Hernia of Intervertebral Disk: Schmorl's Theory

Thanks to the writings of Calve,¹⁰ Gallrand,¹¹ and Beadle, the ideas of Professor Schmorl⁹ are gradually becoming better known. He has collected and examined more than four thousand spinal columns, and his views are of considerable interest and practical importance. He

was the first to point out that the substance of the intervertebral disk might prolapse into the vertebral body.

The intervertebral disk is a complex structure, and consists of the nucleus pulposus, the cartilage plate, and the annulus lamellosus. The *nucleus pulposus* is a remnant of the notochord. It is a semi-fluid structure, and in normal circumstances is under very considerable pressure, estimated by Petter¹² as 30 lb. It varies in its position according to the level of the spine, being placed more anteriorly in the lumbar than in the dorsal region; and it is capable of a certain amount of shifting, depending on the position of the vertebrae above and below it. Its function is to act as a water-cushion and also as a pivot upon which the movements of the vertebrae take place. Being a water-cushion, it distributes the pressure equally over the whole surface of the bones, and prevents any one part of the bone bearing more weight than another. If such a mechanism did not exist—for instance, in the dorsal region, where there is already a normal kyphosis—the anterior parts of the bodies of the vertebrae would bear most of the weight and, according to the laws of growth, would eventually become wedge-shaped. The *cartilage plate* is a layer of hyaline cartilage attached to the surface of the vertebral bodies. On its bony aspect it plays the part of an epiphysis, and on its intervertebral aspect its chief function is to prevent the pressure atrophy of the subjacent bone, due to the turgidity of the nucleus pulposus. The *annulus lamellosus* serves to attach the two cartilage plates to one another, thus encapsulating the nucleus pulposus. Its fibres arise from the matrix of the cartilage plate above, and are inserted into those of the vertebrae below, and also into the fronts of the bodies of the vertebrae and the anterior longitudinal ligament. It is an extremely strong structure, and has a fair amount of elasticity.

It will thus be seen that all the structures of the intervertebral disk are subservient to the preservation of the nucleus pulposus. Since this latter is of great importance to the spine anything which interferes with its turgidity or mobility must be detrimental. During the course of development of the vertebrae, that part of the body in the region of the nucleus pulposus may be defective, so that it becomes, so to speak, encased. All the elements of the disk may be intact and healthy, but since the nucleus pulposus is rendered immobile it is not available for its weight-distributing function, and consequently the vertebrae tend to become wedge-shaped, and kyphosis results. Kyphoses of this nature, though they do not show the typical x-ray appearances, ought to be included in this review of adolescent kyphosis.

The point upon which Beadle lays great emphasis is that, when viewed phylogenetically, the erect posture is a comparatively recent event, so that the spine as a whole has not yet completely adapted itself to its new function—that of weight-bearing. As a result of this, certain elements of it are prone to premature degeneration. That part of the intervertebral disk which is apparently most vulnerable is the cartilage plate. Minute rents can frequently be seen in it, rents which are assumed to be caused, not by any one gross trauma, but by the wear and tear of an ordinary life. Where these rents appear, the nucleus pulposus, owing to its turgidity, insinuates itself and gradually prolapses into the bone. Schmorl has found evidence of these herniae in as many as 38 per cent. of all spines examined. They are always in the lower dorsal and upper lumbar regions, and are of three kinds. The commonest is a vertical protrusion of the nucleus pulposus into the vertebral body; occasionally, if the bone is resistant, the hernia can worm its way anteriorly between the cartilage plate and the bone; and, finally, the herniae may be in front of the nucleus pulposus and consist of the disk substance only.

Schmorl considers that a large number of cases of adolescent kyphosis are the result of these hernial protrusions. Those who support this view explain the radiographic appearances by assuming that the presence of a

foreign body in the bone produces hyperaemia, with its consequent decalcification. Hence the *x*-ray photograph of an early case shows lack of definition. But, as reaction occurs, the bone becomes sclerosed in order to prevent further incursions of the hernia, and it is only when this is completed that the typical moth-eaten conformation can be seen in the *x*-ray film. Furthermore, the hernia theory has some experimental support. Keyes¹³ and Compere¹⁴ very carefully injured the cartilage plate in a dog, and found that disk herniae invariably followed. Mauric¹⁵ quotes the observation of Meyer, who was able to get a necropsy of a case showing typical *x*-ray appearance, and found that the indentations corresponded to a discal hernia. It can therefore be taken for granted that these herniae do exist.

Examination of Schmorl's Theory

The first criticism which comes to mind is that, if discal herniae are so common as to occur in 38 per cent. of spines, why is adolescent kyphosis such a comparatively rare condition? The answer seems to be that the point of chief importance is the age at which these herniae arise. If they appear in later life, in the line of the nucleus pulposus, which is the commonest site, the secondary changes in the spine are those of an osteoarthritic nature, owing to the loss of function of the nucleus pulposus; but, if they appear earlier they give rise to abnormalities of growth. Schmorl is under the impression that these herniae are of congenital origin, or, alternatively, that there is a congenital weakness of the cartilage plate sufficient for it to undergo early degeneration. Anyone who has seen Schmorl's pictures, or read Beadle's account, cannot doubt that congenital abnormalities of the disk do exist, but I am not aware of any developmental reason why the lower dorsal and upper lumbar regions—the parts most affected in adolescent kyphosis—should be more prone to congenital malformation than any other. Also, I do not see the necessity of invoking the aid of such a hypothesis as a predisposition to premature degeneration of the cartilage plate in order to support Schmorl's theory, because that part of the spine is the most vulnerable and most liable to flexion traumata in any circumstance.

Those who oppose Schmorl's hypothesis do so because they think that it does not explain all the radiographic findings. We have already seen how some of them—namely, the early decalcification and later sclerosis—can be explained; but it is more difficult to account for the late appearance, the large size, and the marked opacity of the centres of ossification of the epiphyseal ring. Too much stress should not be laid upon the time factor in the appearance of these centres of ossification, because it is known to vary. But there is no doubt that when they do appear the *x*-ray picture is very similar to the changes seen in osteochondritis elsewhere. In all these latter the density is said to be due to necrosis of the bony nucleus. There is one important distinction, however, and that is that in adolescent kyphosis the dense centres are larger than normal, whereas in osteochondritis they are invariably smaller. Furthermore, I think that in adolescent kyphosis these centres fuse with the body of the vertebra earlier than usual—a fact that can hardly be reconciled with an idea that presupposes death of the bone.

It is customary, when one sees radiographic changes in epiphyses, to regard them all as pathological, but the point I would like to make is that we do not know what changes, if any, take place in circumstances of a reactive nature which demand the rapid appearance and rapid fusion of an epiphysis. I am inclined to regard the changes in the centres of ossification of the epiphyseal ring as evidence of reaction against the invasion of a hernia, as an attempt to hasten its fusion with the body

in order to offer a greater obstacle to the incursion of a peripherally placed hernia.

To sum up, then: though some cases of adolescent kyphosis may result primarily from congenital abnormalities of the intervertebral disk, I think it is more reasonable to regard the discal herniae as secondary changes and as the inevitable complication of any process which weakens the cartilage plate or the underlying bone. This weakness may occasionally be caused by the variety of conditions already referred to, but the most important factor is stress and strain due to an abnormally heavy body, and more especially oft-repeated minor traumata.

The Effect of Stress and Strain

The factors which increase strain and stress are: (a) body weight, (b) trauma, and (c) short, hamstring muscles. Most of the theories so far examined presuppose the existence of an exciting cause—and that is

DIAGRAM I

A, Normal position for toe-touching. Note that contour of the back is regular. Anterior superior spine of the ilium on the same horizontal plane as the top of the great trochanter. Spring in the hamstring muscles not stretched.

B, Normal back flexed beyond comfortable limit. Note that the contour of the back is unchanged. Anterior superior spine below the level of the great trochanter. Hamstring spring stretched.

C, Short hamstrings. Note that the anterior superior spine is above the level of the great trochanter. Contour of the back is normal.

D, Short hamstrings. Back flexed beyond normal limits, showing the increased convexity of the lower dorsal and lumbar regions.

generally held to be stress and trauma. Reference has already been made to the influence of body weight in discussing the endocrine theory, and there is no need to enlarge upon the accident of a strong flexion force in a growing child as a cause of injury to the spine. But since the history of trauma often cannot be elicited, one must look for another explanation.

When a normal child (Diagram I—A, B, C, D) stoops down to touch his toes with the knees extended the contour of the back is regular and graceful, and the hamstring muscles are not tight. In this position the back itself is locked in full flexion, but the pelvis is not fixed, as there is some give in the hamstring muscles. Therefore, if a force falls upon the back, making it flex further, the hamstring muscles act as a spring (Plate, Figs. 1 and 2). On the other hand, if the hamstring muscles are tight, then in the stooping position not only is the back flexed to its maximum but the pelvis is fixed, for there is no spring action in the hamstring muscles. Since the back

of a child, even when fully flexed, is more resilient than the contracted muscles are stretchable, any force falling on the back will tend to hyperflex the spine and throw all the weight on the anterior parts of the bodies of the vertebrae (Figs. 3 and 4).

Influence of Hamstrings on the Back

Several years ago, when treating a child for bad posture by the usual method of remedial exercises, I noticed that it gradually got worse. Rotation of the lumbar vertebrae, which had not existed, became apparent. On further examination I found that the hamstring muscles were short—more so on the side of the rotation. With the kind permission of the medical officer of health and the school authorities of the L.C.C. I have examined a large number of school children for two years in succession with the idea of determining what proportion of them had short hamstring muscles. I found that it was common, but rarely existed before the age of 6. It was more frequently unilateral than bilateral, and in the former there was invariably rotation of the lumbar vertebrae towards the shortened side. Sometimes, even, the rotation was generalized. It was rare to find both hamstring muscles equally short, but when it did exist the contour of the back in flexion was much more curved (Figs. 5 and 6), the point of the greatest convexity being the lower dorsal and upper lumbar regions. In the bilateral cases, however, it was more common to find one side shorter than the other—usually the left—in which case there was always rotation of the lumbar vertebrae to the shortened side (Figs. 7, 8, and 9), and the point of greatest convexity in the contour was always in the lower dorsal region.

It was interesting to note that in the majority of cases the shortening of these muscles was transient. Children who were unable to touch toes by six inches or more in one year could do so the next, while some who could the first year were not able to the following year. This latter was most evident in children who had grown rapidly in the interval. In a smaller proportion of cases there was no tendency to improvement, and this was most marked in the long, lanky, flat-backed child, but not invariably so.

These are facts that can be verified by anybody who takes the trouble to do so. The point of interest is whether they have any bearing on the subject under discussion. I think they have. It seems to me that the back of a child which has not got the protective spring action of the hamstring muscles must be regarded as a vulnerable back. The inability to touch toes is in itself not important, but it is the loss of the spring action, due to the shortness of the hamstring muscles, that matters. It may be argued that bending down with the knees extended, a position in which the spring action is most necessary, is not a common attitude for a child to adopt; but one must remember that sitting up from the recumbent position is the equivalent of it (Figs. 10, 11, and 12), that it is frequently assumed when playing leap-frog, and that, most important of all, toe-touching is one of the routine exercises in the gymnasium classes at school.

I have seen children who are unable to touch their toes being exhorted to do so by a series of sudden jerks. The practice of using the back of a growing child as a lever (and a flexible one at that) to stretch the comparatively unstretchable hamstring muscles is a pernicious one. Such movements must cause considerable pressure on the front of the bodies of the vertebrae, and, as judged from the contour, it is upon the lower dorsal and upper lumbar regions that the brunt of the force falls. If the force is sufficiently powerful and frequent it is not difficult to conceive of minor injuries, such as small crush fractures or subchondral haemorrhages, occurring in the region of

the epiphyseal plaques. Furthermore, and most important of all, when one reflects that the annulus lamellosus arises from the matrix of the cartilage plate (Diagram II—A and B), forced movements of the annulus lamellosus might easily cause those mysterious fissures in the cartilage plate which are known to be the precursors of discal herniae. Owing to the fact that there are no nerve endings in the intervertebral disks, these minor injuries do not give rise to pain, and no opportunity is given them to repair. This seems to me to account for the fissures in the cartilage plate more satisfactorily than to imagine that the plate itself is a structure which sometimes has a congenital predisposition to premature degeneration.

DIAGRAM II

To show the origin of fissures in the cartilage plate

A, In the normal resting position. Note the fibres of the annulus lamellosus arising from the matrix of the cartilage plate.

B, Showing forcible flexion. The nucleus pulposus is pinched as a cherry-stone between finger and thumb, causing strong traction on the posterior part of the annulus lamellosus, which pulls on the cartilage plate, causing it to rupture.

1 = Cartilage plate. 2 = Nucleus pulposus. 3 = Annulus lamellosus. 4 = Rent in cartilage plate.

In conclusion, I am a profound believer in Schmorl's theory, but I doubt if any but a very few cases of adolescent kyphosis are the effect of congenital causes. The key to the problem lies in those mysterious fissures in the cartilage plate which I believe arise from flexion injuries. During the rough and tumble of play any child might sustain a flexion injury sufficient to produce these fissures, but I believe that the back of a child whose hamstring muscles are short is more susceptible to traumata of this nature, particularly if his general musculature is poor on account of previous debility or over-growth. I would go even further, and say that not only do short hamstring muscles predispose to flexion injuries, but they also give rise to rotation of the vertebrae and ultimately to scoliosis. If I have succeeded in convincing you that shortening of the hamstring muscles is an important factor, then we ought to agree that children with that condition should be watched with the utmost care and intelligence at school, and that toe-touching exercises in gymnastic classes should be condemned as a routine practice.

My thanks are due to Dr. C. J. Thomas for arranging for me to examine the school children, and also to the head master and head mistresses of the Laxon Street and Snowfield Schools for their courtesy and help. I should also like to thank Dr. B. Armstrong and Mr. Seddon for allowing me to see their cases and x-ray photographs.

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FIG. 1.—Normal child. Touching toes comfortably. Note anterior superior spine on same level as great trochanter.

FIG. 2.—Same child made to flex further. Note contour of the back unchanged. Anterior superior spine a little below level of great trochanter.

FIGS. 3 AND 4.—Cases to show how pressure on a child with short hamstring muscles hyperflexes the back and does not stretch the hamstring muscles.

FIGS. 5 AND 6.—Cases to show increased curve of back in children with bilateral shortening of the hamstring muscles.

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FIG. 7.—Child with short hamstring muscles. Left shorter than the right. Note rotation of vertebrae to left.

FIG. 8.—Bilateral shortening of hamstring muscles. Right shorter than left. Note rotation of vertebrae to right.

FIG. 9.—Right hamstring muscle shorter than left. Note rotation of vertebrae to right.

FIGS. 10, 11 AND 12.—Cases to show abnormal contour of the back in sitting position in children with short hamstring muscles. If such children suffered from an illness requiring them to be nursed in the propped-up position the fronts of the bodies of the vertebrae would be subjected to a continuous pressure, which would be greatly increased during a paroxysm of coughing. All children with short hamstring muscles ought as a routine to be nursed with pillows under their knees.