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Transmission of weight through the lower thoracic and lumbar regions of the vertebral column in man

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INTRODUCTION

Recently it has been suspected that the neural arch component of a vertebra, beside its contribution to the formation of the vertebral canal and the role of its articular processes in governing the range and direction of movement between two vertebrae, is also involved in weight bearing (Denis, 1983; Louis, 1985). Very recently Pal & Routal (1986), on the basis of measurements of the vertebral column and mathematical calculations, have provided strong evidence for the role of the neural arch in the weight transmission through the cervical and upper thoracic region of the vertebral column. It was shown that in the cervical part of the vertebral column an almost equal amount of weight is borne by the body and the neural arch. In fact in the cervical region weight is transmitted through three columns, i.e. an anterior column formed by bodies and intervertebral discs and two posterior columns formed by articulations of articular processes. However, because of the incorporation of bar-like articular processes into the laminae at the level of C7 and below, these two separate posterior columns cannot be traced in the thoracic region. Hence, according to the above study, in the upper thoracic region weight is transmitted through two columns, one anterior similar to that in the cervical region, and one posterior formed by the successive articulation of laminae at their articular facets together with their posterior ligamentous complexes. At the junction of the cervicothoracic curvatures, with the shifting of the line of gravity from posterior to anterior, a part of the posterior column weight is transferred to the anterior column through the pedicles.

In continuation of the above work and using the same basic mechanical principles of weight transfer, the role of the neural arch in the lower thoracic and lumbar regions has been investigated. An attempt has also been made to find the relative magnitude of the compressive force passing through the vertebral column via its two components, body and neural arch.

MATERIAL AND METHODS

To investigate the weight transmission in the lower thoracic and lumbar regions of the vertebral column the same 44 adult columns used in the previous investigation (Pal & Routal, 1986) were used.

Measurements of the vertebrae from T_5 to L_5 were taken. Vertebrae T_6, T_7, T_8 and L_2 did not differ much from their neighbouring vertebrae so their measurements are not presented.

The following measurements were taken: mean body area (area of the inferior surface of the body); mean inferior articular facet area; mean pedicle index; mean

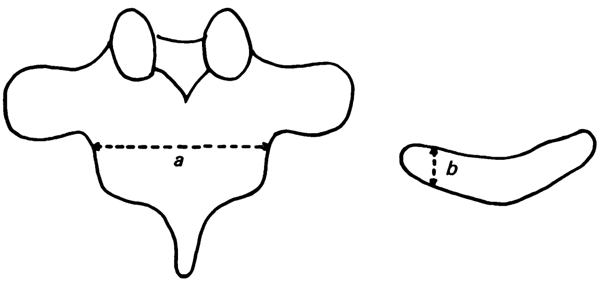

Fig. 1 (*a–b*). The lamina index is the product of (*a*) and (*b*). Both (*a*) and (*b*) were measured just above the inferior articular facet. (*a*) Width of the lamina. (*b*) Thickness of the lamina.

Table 1. *Vertebral dimensions at various levels*
Mean value ± S.D. in cm^2

Vertebral level	Mean body area	Mean inferior articular facet area	Mean lamina index	Mean pedicle index	Mean arch index
T_5	5·34±0·45	0·83±0·06	1·25±0·36	0·40±0·07	4·00±0·67
T_8	7·30±1·98	1·01±0·29	1·43±0·24	0·52×0·15	4·60±1·01
T_9	7·91±2·16	1·10±0·30	1·60±0·37	0·80±0·33	4·94±0·47
T_{11}	8·82±1·10	1·05±0·25	1·28±0·36	1·01±0·26	4·43±0·50
T_{12}	10·24±1·53	0·90±0·31	1·25±0·27	0·96±0·24	5·14±0·89
L_1	11·46±2·16	1·10±0·27	1·42±0·19	0·81±0·18	5·42±0·09
L_3	13·82±2·22	1·51±0·28	1·79±0·30	1·14±0·02	6·52±1·05
L_4	14·17±1·26	1·69±0·34	2·26±0·53	1·43±0·08	7·25±1·00
L_5	14·07±2·77	1·93±0·78	3·01±0·89	2·01±0·37	8·61±0·57

arch index and body–pedicle angle. (These parameters are selected on the basis of mechanical principles and have been fully discussed in our previous paper.)

In addition, the lamina index was used for the present study. This is an index which represents the cross sectional area of the lamina. It is obtained by the product of transverse distance and thickness of the lamina just above the inferior articular facets (Fig. 1).

In the thoracic and lumbar region articular facets are incorporated in the lamina itself (Fig. 7) and do not form a separate bar-like mass as in the cervical region. Hence, the compressive force acting at the superior articular facets will be transmitted to the inferior articular facets through the laminae. Thus, a cross sectional area of the lamina will represent the magnitude of the compressive force transmitted through it (Pal & Routal, 1986). In other words, the compressive force transmitted through the laminae should be the same as that transmitted through the two inferior articular facets. Hence, in the lower thoracic and lumbar regions (to have a double check) weight transmission through the posterior column was analysed by both parameters, i.e. the inferior articular facet area and the lamina index.

The size of the bodies gradually increases from above downwards, but the neural arch measurements do not follow the same trend. Interpretation of data on the basis of these parameters alone may thus be confusing. Hence, the size of the articular facet, and the pedicle, the lamina index and the arch index were compared with the body surface area at various levels. Thus the four ratios, pedicle index/body area, articular facet/body area, lamina index/body area and arch index/body area, were calculated.

Table 2. *Ratios at various levels*

Vertebral level	Articular facet area/body area	Lamina index/ body area	Pedicle index/ body area	Arch index/ body area
T_5	0·15	0·24	0·07	0·74
T_8	0·13	0·20	0·07	0·63
T_9	0·13	0·20	0·10	0·62
T_{11}	0·11	0·14	0·11	0·50
T_{12}	0·08	0·12	0·09	0·50
L_1	0·09	0·12	0·07	0·47
L_3	0·11	0·13	0·08	0·47
L_4	0·12	0·15	0·10	0·51
L_5	0·13	0·21	0·14	0·61

OBSERVATIONS

The various measurements that were made are presented in Table 1. The mean body area showed a gradual increase from above downwards. The areas of the inferior surfaces of L_4 and L_5 were each almost double the area of T_8. The mean inferior articular facet area showed an increase from T_5 to T_9 followed by a decrease as far as T_{12} and then an increase to L_5. The pedicle index increased gradually down to T_{11} followed by a decrease to L_1 and then an increase to L_5. This mean arch index showed a gradual increase from T_5 to L_5.

Various ratios are presented in Table 2 (Figs. 2–5).

Articular facet area/body area

The mean articular facet area in relation to the body area at different levels in the lower thoracic region showed a decline to the level of T_{12} and thereafter it increased again.

Lamina index/body area

This ratio also showed a decline to the level of T_{12} followed by a gradual increase to L_4 and then a sudden increase to L_5.

Pedicle index/body area

This showed a biphasic curve, the pedicles in relation to the body being relatively weak at T_5, T_8, L_1 and L_3 and strong and almost of equal strength between T_9 and T_{12}. Similarly particles again became strong at L_4 and L_5 levels.

Arch index/body area

This ratio fell gradually from T_5 to L_3, indicating that articular processes and laminae approach more closely to the body down to L_3. The ratio increases again for L_4 and L_5, indicating that the articular processes and laminae are further away from the body at these levels.

Body–pedicle angle

At all vertebral levels (from T_5 to L_1) the pedicles were directed upwards and backwards from the body towards the laminae. However, the pedicles at L_3 and L_4 were nearly horizontal (Table 3).

Since the cross sectional area of a column at a particular level represents the magnitude of weight transmission, the surface area of the body and of the right and

Table 3. *Angle between pedicle and body*

Vertebral level	Mean angle	Range	S.D.
T_5	111°	103°–114°	±6·30
T_8	108°	105°–110°	±2·12
T_9	109°	105°–116°	±3·40
T_{11}	109°	104°–115°	±3·71
T_{12}	110°	106°–120°	±4·51
L_1	95°	90°–102°	±3·95
L_3	93°	85°–99°	±5·53
L_4	91°	85°–95°	±3·22
L_5	97°	92°–104°	±5·71

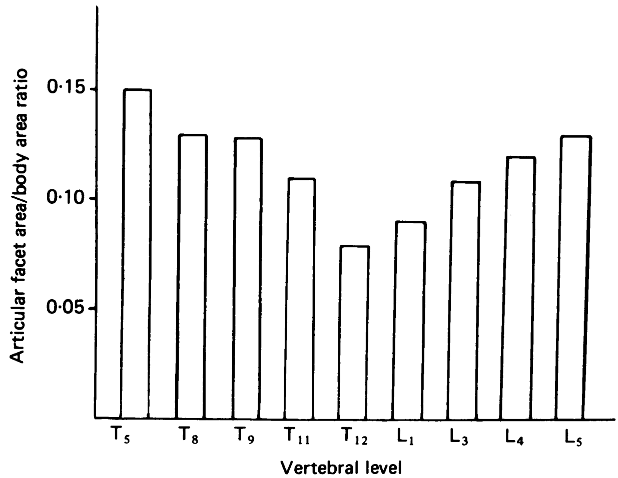

Fig. 2. Articular facet area/body area ratio.

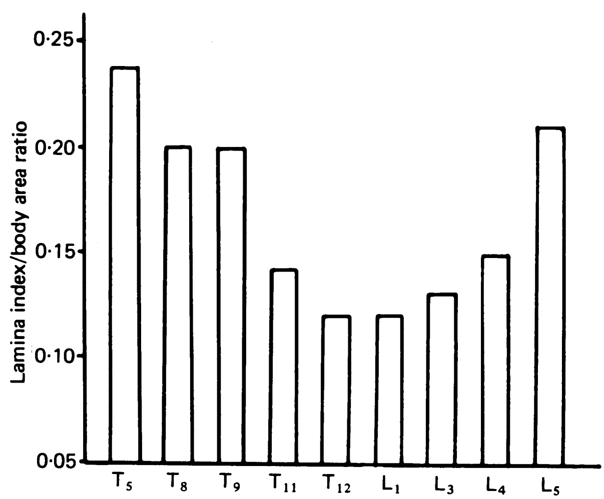

Fig. 3. Lamina index/body area ratio.

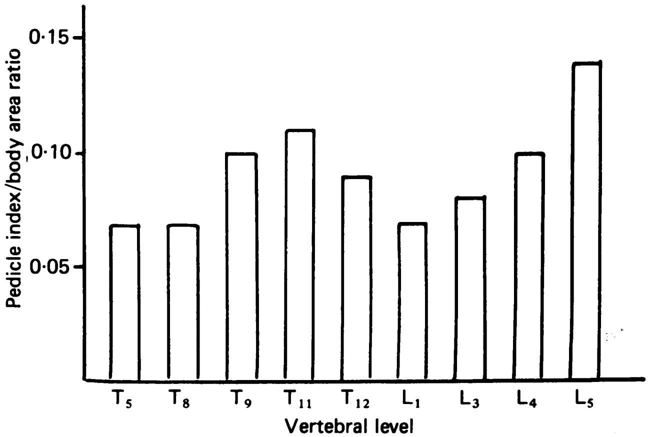

Fig. 4. Pedicle index/body area ratio.

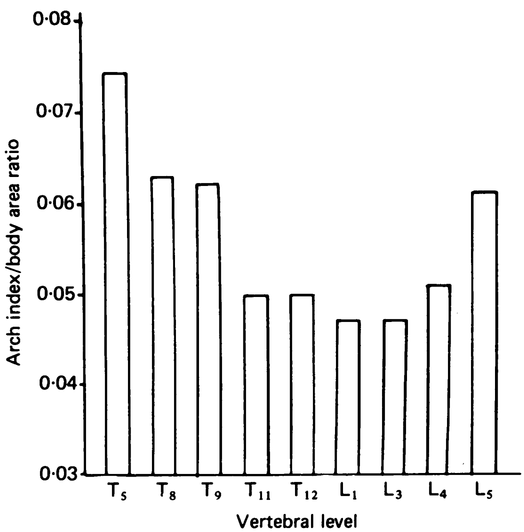

Fig. 5. Arch index/body area ratio.

left articular facet (or the cross sectional area of the laminae) will represent the total weight transmitted at that level. The area of the body and the two articular facets was summed and considered as the total (100%) weight bearing area, from which the percentage area of the body and the two facets were calculated separately (Table 4). The percentage area of the two articular facets gradually declined to the level of T_{12}, after which it again increased from the level of L_1. The percentage area of the body in relation to that of the articular facets was found to be maximal at the level of T_{12}, after which it gradually declined. Similarly when the area of the body was compared to the cross sectional area of the laminae (lamina index) it followed the same trends (Table 5). The percentage area of the laminae gradually decreased and at T_{12} was only 10·87% (minimum) in relation to the area of the body. From L_1 onwards it again started to increase.

Table 4. *Percentage area of body and articular facets at various vertebral levels*

Vertebral levels	Total area (body+facets)		Body area		Area of two articular facets	
	Cm²	%	Cm²	%	Cm²	%
T_5	7·00	100	5·34	76·28	1·66	23·71
T_8	9·32	100	7·30	78·32	2·02	21·68
T_9	10·11	100	7·91	78·23	2·20	21·76
T_{11}	10·92	100	8·82	80·76	2·10	19·23
T_{12}	12·04	100	10·24	85·04	1·80	14·95
L_1	13·66	100	11·46	83·89	2·20	16·10
L_3	16·84	100	13·82	82·06	3·02	17·93
L_4	17·55	100	14·17	80·74	3·38	19·25
L_5	17·93	100	14·07	78·47	3·86	21·52

Table 5. *Percentage area of body and cross sectional area of lamina at various vertebral levels*

Vertebral levels	Total area (body+lamina)		Body area		Area of lamina	
	Cm²	%	Cm²	%	Cm²	%
T_5	6·59	100	5·34	81·03	1·25	18·96
T_8	8·73	100	7·30	83·61	1·43	16·38
T_9	9·51	100	7·91	83·17	1·50	15·77
T_{11}	10·10	100	8·82	87·32	1·28	12·67
T_{12}	11·49	100	1·24	89·12	1·25	10·87
L_1	12·88	100	11·46	88·97	1·42	11·02
L_3	15·61	100	13·82	88·53	1·79	11·46
L_4	16·43	100	14·17	86·24	2·26	13·75
L_5	17·08	100	14·07	82·37	3·01	17·62

To summarise these observations one can say that the body surface area gradually increased from T_5 to L_4 but the area of the inferior surface of L_5 was less than that of L_4. In relation to the body area, the pedicles were stronger between T_9 and T_{12} and became strong again at L_4, reaching a maximum at L_5. The articular facet area and the lamina cross sectional area diminished down to T_{12} and gradually increased again from L_1 to L_5; arch size gradually diminished to L_3 and increased again at L_4 and L_5. Pedicles were inclined upwards and backwards from the body to the lamina in most of the vertebrae.

DISCUSSION

Previous work (Pal & Routal, 1986) revealed that in the upper thoracic region weight is transmitted through two columns. Hence, it was suspected that this would also be true for the lower thoracic and lumbar regions as the morphological structure of the neural arch remains almost the same at these levels. Analysis of data presented in this study has confirmed the presence of two columns, the anterior column being formed by bodies and intervertebral discs and the posterior by successive articulations of laminae.

The observations of the present study can be interpreted as follows.

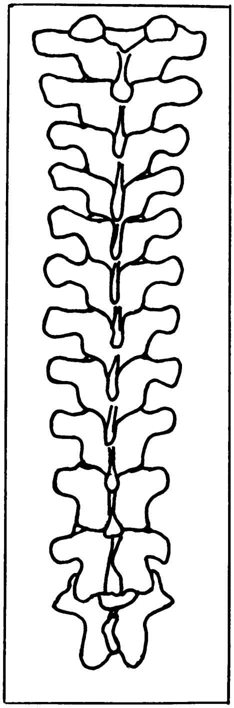

Fig. 6. Posterior aspect of thoracic spine. Note the successive articulations of laminae to form a single posterior pillar. Also note the relative sizes of the laminae.

Magnitude of weight passing through two columns

Since the transmission of load is presumed to be through the body and laminae at each vertebral level, their cross sectional area at any particular level will represent their ability to resist longitudinal compressive forces passing through the vertebral column at that level. The magnitude of the compressive force passing through the posterior column can also be obtained from the area of the inferior articular facets. The body surface area gradually increases from T_5 to L_4, indicating that from above downwards more and more weight is borne by the anterior column. The significantly smaller area of L_5 body as compared to L_4 indicates that some of the compressive force from L_5 is diverted before it reaches to its inferior surface (see below).

On the other hand the lamina index and the mean articular facet area show a gradual increase from T_5 to T_{10} followed by a decrease from T_{11} to T_{12} (Table 1). These data indicate that weight passing through the posterior column gradually increases from T_5 to T_{10}, while in the upper thoracic region (Pal & Routal, 1986) a reverse trend is observed. There the mean articular facet area gradually decreases from T_1 to T_4. This peculiar trend of articular facet area and lamina index (a decrease in lamina size from T_1 to T_4 followed by an increase from T_5 to T_{10} and once again a decrease at T_{11} and T_{12}) is also evident on naked eye observation of the vertebral column from the posterior aspect (Fig. 6). Why does the lamina size increase from T_5 to T_{10} when there is a tendency for it to fall from T_1 to T_5? This indicates that from T_5 onwards, the posterior column is carrying more weight than was transmitted at T_4 and T_5. This weight must have come from outside and is in addition to the weight coming from above. It is suspected that it is transmitted through the ribs via the costo-transverse articulations and ligaments. Since the size of the ribs increases from above downwards (1 to 10) it is inferred that the lower ribs carry more weight than the upper. Thus the load brought to the posterior column (laminae) through the ribs increases from vertebral levels T_1 to T_{10}. However, the first rib, because of its close approximation to the sternoclavicular joint and its attachment to the clavicle by means of the costoclavicular ligament, might be involved in carrying more of the weight of the upper limb than do the other ribs. In addition to weight transmitted by the ribs, the laminae at T_1 receive almost all the weight transmitted by the two posterior cervical columns (Pal & Routal, 1986). A considerable part of this load from the laminae of T_1 is transmitted to lower laminae (T_2 and T_3) and from the laminae of these vertebrae (T_1 to T_3) a major part of this load is transmitted to the bodies (anterior column) through their strong and inclined pedicles. Thus the posterior column in the uppermost thoracic region receives much more weight than the middle thoracic region. Hence, T_1 and T_2 facet areas and lamina indices are much greater than those of T_5. This explains why the lamina size decreases from T_1 to T_4. Since the 11th and 12th ribs are small and do not transmit their load to the transverse processes their lamina indices and facet areas decrease gradually.

Because of the inclination of the pedicles towards the bodies (Table 3) and the anterior curvature of the spine in the thoracic region there is a tendency for the load to be transmitted from the posterior to the anterior column. Thus at each vertebral level the load brought to the posterior column through the ribs is transferred to the anterior column through the pedicles. Probably the proportion of weight transferred to the anterior column at each level is almost the same as that received via the ribs at that level. This is indicated by a slow increment in the lamina index at each level, otherwise the increment in lamina size from above downwards would have been in the same proportion as that of the size of the bodies.

The interpretation of lamina index/body area ratio and articular facet area/body area ratio in the thoracic region is misleading when analysed alone. The weight transmitted through the ribs first reaches the posterior column and is immediately transferred to the anterior column. Thus at each level body size increases greatly compared to the increase in area of the laminae or articular facets. Hence, in spite of a gradual increase in lamina index and mean articular facet area the ratio of these measurements to the body surface area shows a gradual decrease. This again suggests that at each level the load brought by the ribs to the laminae is immediately transmitted to the anterior column.

In the lumbar region the mean articular facet area, the lamina index and their ratio with the body area showed a gradual increase from L_1 to L_3 with a sudden increase at L_4 and L_5. This indicates that the lower portion of the posterior column (L_4 and L_5) transmits more compressive force than the upper.

Data presented in Tables 4 and 5 help to estimate the proportion of the weight that passes through the anterior and posterior columns separately. The magnitude of load passing through each column, as presented in Tables 4 and 5, is true only for the body when it is in the anatomical position. The load will change between the two columns under different static and dynamic conditions of the body. At T_{12} level, the posterior column carries the least proportion of the load passing through the spine at that level while at L_5 level about 23 % of the total weight is borne by the posterior column (Table 5). Adams & Hutton (1980) and Yang & King (1984) found that lumbar facet joints are capable of transmitting a compressive force. They tested the proportion of load transmitted through the facet joints experimentally, on isolated lumbar vertebrae, by means of a load testing machine. Adams & Hutton found that about 16% of the total weight is transmitted through the facet joints while Yang & King found it to be between 3 and 25%. Dietrich & Kurowski (1985) are also of the opinion that although the column formed by the vertebral bodies is the main load-bearing structure, the vertebral arches are also highly loaded elements.

The similar trend of the lamina index/body area ratio and the articular facet/body area ratio provides strong evidence that the laminae are involved in weight transmission and that there is a single posterior column in this region. This is in marked contrast to the concept of Louis (1985) who believes that there are two posterior columns in the thoracic and lumbar regions, as has been found in the cervical region. But it should be noted that the morphology of cervical vertebrae is quite different from that of the thoracic and lumbar vertebrae. In the cervical region there are two distinct posterior columns due to the bar-like articular processes to which the load is confined. In the thoracic and lumbar regions the articular processes are completely incorporated into the laminae, so that the load passing from superior to inferior articular facets will diffuse into the lamina.

Transfer of weight from one column to the other

The anterior and posterior columns run parallel to each other following the thoracolumbar curvature. These two columns, at each vertebral level, are connected to each other by pedicles whose inclination (Table 3) and strength (Table 2) vary at different levels.

Since the lower ribs carry more weight (except for T_{12}) as compared to the middle ribs in the series, the pedicle index and the pedicle index/body area ratio were found to be greater at that level. It is interesting to note at this stage that the ribs will transmit their load first to the laminae through the costo-transverse articulation. From the laminae the load will pass to the next vertebra through the joints of the articular facets and will ultimately reach the body of the vertebra through its pedicles. Hence, the load from the ribs will always go to the body of the vertebra below. This explains why the T_{12} pedicles are strong in spite of the rudimentary 12th rib. This also explains why the pedicles at L_1 are weak.

In the upper lumbar region, where the pedicle index/body area ratio is low (pedicles are weak and are also nearly horizontal), minimum transfer of weight between the two columns is expected. Thus the neural arches from L_1 to L_3 must be involved only in downward transmission of the load received by T_{12} together with the segmental load which is added at each vertebral level. At level L_4 pedicles are strong; articular facet/body area ratio increases, the body surface area does not increase as much as does the area at L_3 and the proportion of the load passing through the posterior column increases (Tables 4 and 5). All the above facts suggest that a part of the compressive force from the anterior column is transferred to the posterior column (laminae).

According to Davis (1961) and to our own observations there is a reduction in the surface area of L_5 as compared to L_4. The reduced surface area of the body, the strong pedicles and high articular facet/body area ratio indicate that a considerable part of the load from L_5 body is transferred to its laminae. We can therefore support his concept that the neural arch at the level of L_5 plays a role in load transmission.

At level L_5 where transfer of weight from the anterior to the posterior column is suspected, load through the pedicles has to pass in an 'antigravity' direction, i.e.

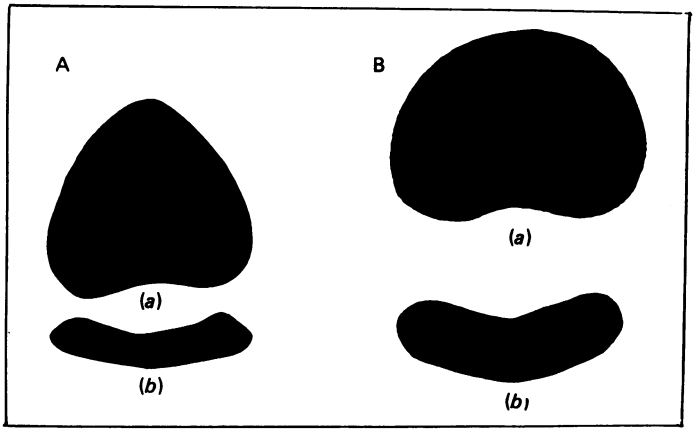

Fig. 7. (A–B). Diagrammatic representation of the positions of the two weight-bearing columns of the vertebral column in the thoracic (A) and lumbar (B) regions. (*a*) Cross section of the anterior column formed by the bodies. (*b*) Cross section of the posterior column formed by the laminae.

opposite to the direction of inclination of the pedicles. This is possible because of the inclined position of the body of L_5. In an inclined beam which is connecting the two columns load will only pass towards gravity. But if such a beam is free towards its lower end it will transmit the load even against gravity. L_5 (and to a certain extent L_4) is so placed that it tends to slide forwards and downwards towards the pelvic cavity. This sliding tendency is prevented by the lumbosacral zygapophyseal joint which helps to hold it in position. Thus the body and pedicles of L_5 can be likened to an inclined beam which is free at the lower end and is fixed posteriorly at the lumbosacral articular facets. Transfer of load from the body to the laminae in L_5 (and to a certain extent in L_4) will thus be upwards against gravity through the strong pedicles.

To summarise the above discussion it may be said that in the thoracic region, where the curvature is concave anteriorly, the load is transmitted from the posterior to the anterior column and in the lumbar region where the curvature is concave posteriorly the load is transmitted from anterior to posterior. This shifting of load is in accordance with the position of the line of gravity.

Relative positions of the columns

The position of the weight-bearing columns relative to each other is important. When columns are placed away from the centre of load they can resist bending or buckling forces and are more stable than columns which are placed closer to each other (Fig. 7).

It will be evident from the arch index/body area ratio (Table 2) that in the lower thoracic region the posterior column lies relatively close to the anterior column. This is due to the fact that the weight is transferred from the posterior to the anterior column in this region and the line of gravity passes in front of the vertebral column. But in the lumbar region the posterior column moves away from the anterior column (articular processes and laminae are placed at a greater distance from bodies), especially in the lower lumbar region. This is because weight is transferred from the anterior to the posterior column and the line of gravity passes posterior to bodies in this region.

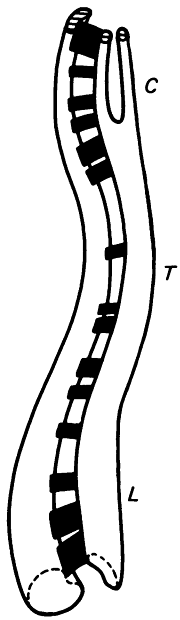

Fig. 8. Diagrammatic representation of weight transmission through the various regions of the vertebral column. In the cervical region (*C*) weight is transmitted through three columns while in the thoracic (*T*) and lumbar (*L*) regions it is transmitted through two columns. Thick black staples connecting the two columns represent pedicles. Note the direction and thickness of pedicles. Pedicles are shown on one side only.

Clinico-pathological interpretations

From the present and the previous study (Pal & Routal, 1986) a new concept for the stability of the spine has been generated. This model of the spine (Fig. 8) is capable of explaining various complicated clinico-pathological conditions.

Instability of spine following laminectomy

About 40% of the load in the cervical region is transmitted through the two posterior columns and about 20% passes through laminae in the lumbar region (Table 4). Thus even the slightest interference with these columns during extensive laminectomy leads to excessive strain on the anterior column. This column is not capable of bearing this extra strain and eventually fails. This explains the aetiology of instability in the lumbar region and progressive kyphosis and swan neck deformity in the cervical region following laminectomy (Cattell & Clark, 1967).

This study very strongly recommends the preservation of the integrity of the articular facet joints in laminectomy.

Fractures of the spine

Common sites for fractures and degenerative changes of the spine are the sites where transfer of weight occurs between the columns. It seems probable that the mechanism of load transfer between columns makes the region susceptible to fracture.

Spondylolysis

The present finding that at L_4 and L_5 levels a considerable part of the compressive force is transferred from the anterior column (body) to the posterior (laminae), through the pedicles, has provided an explanation for the aetiology of spondylolysis and spondylolisthesis. This transfer of weight is due to the peculiar orientation (forward and downward inclination) of these vertebrae. Since body and pedicle at these levels lie in almost the same inclined plane, forces from body to lamina through the pedicles pass in the same direction. But since the inferior articular processes (which interlock with the sacrum in the case of L_5) are at right angles to the long axis of the pedicles, forces change their direction at an acute angle to reach the inferior articular facet. The site for the change in direction of forces is at the pars interarticularis which sustains the stress. This may lead to a crack in the pars interarticularis (spondylolysis) and the tendency of forward slip of the vertebral body may then result in spondylolisthesis.

Low back pain

Since the neural arch at L_4 and L_5 levels is involved in transmission of a considerable load (Tables 4 and 5), this indicates that the joints between the articular facets may be a site for low back pain. Probably the pain is due to stretching of the joint capsule (or transmission of load across it) which contains a nociceptive Type IV receptor system (Nade, Bell & Wyke, 1980).

Scoliosis

The posterior column in the thoracic region is the first to receive the maximum load from the ribs through the costo-transverse articulations and this provides a satisfactory explanation for the aetiology of scoliosis. This can be explained as follows.

In normal conditions vertical stability of the thoracic spine is maintained by equal support from the ribs on both sides and probably equal weight is brought to the posterior column from both sides. Any interference with this balanced mechanism will disturb the mechanism of spinal stability so that the spine will bend towards the heavier side. Thus unequal growth of ribs, disease and tumours of the chest wall, thoracotomy and thoracoplasty (Loynes, 1972; Durning, Scoles & Fox, 1980), operations on the posterior end of the ribs (Langenskoiold & Michelsson, 1961) and hemilaminectomy, lung pathology and paralysis of muscles (e.g. in poliomyelitis) will interfere with the symmetrical weight transfer through the ribs. Since the ribs are responsible for transmission of weight of the upper limbs to the vertebral column, congenital deficiencies of the upper limb have been associated with a high incidence of scoliosis. Similar association has been reported between asymmetry of breast size and scoliosis (Sevastik, Aaro & Normelli, 1984).

The present study is the first to reveal the mechanism of production of scoliosis by indicating that the ribs are significantly involved in weight transmission and that they carry a considerable part of the weight to the laminae via the costo-transverse articulations. However, the factor which leads to asymmetrical weight transmission through the ribs in idiopathic scoliosis is yet to be investigated.

In addition to the part played by the ribs, the closer position of the two columns (low arch index/body area ratio) in the lower thoracic region and the high magnitude of load transmission through the anterior column (Tables 4 and 5) probably make this region more susceptible to scoliosis.

SUMMARY

This study is an attempt to investigate the role of the neural arches in transmission of weight in the lower thoracic and the lumbar regions of the vertebral column. Based on simple mechanical principles of weight transmission, various parameters were chosen for measurements at each vertebral level. In 44 adult male dry vertebral columns measurements were made from T_5 to L_5 levels. The area of the inferior surface of the body at each vertebral level was compared with the area of the inferior articular facet, the cross sectional area of the laminae (lamina index), the pedicle index and the arch index. The inclination of the pedicles in relation to the body was also measured at each level. On the basis of the above measurements it was deduced that the compression force in the lower thoracic and lumbar regions is transmitted through two parallel columns, one anterior (formed by bodies and intervertebral discs) and one posterior (formed by successive articulations of laminae with each other at their articular facets).

This study suggests that a considerable part of the weight of the upper limbs and the thoracic cage is transmitted through the ribs to the posterior column (laminae) through the costo-transverse articulations and ligaments. Because of the inclined position of the fifth lumbar vertebra, a significant part of the compressive force from the body is transmitted to the laminae in spite of the anterior inclination of the pedicles at this level. Because of the anterior concavity of the spine in the thoracic region, weight is transferred from the posterior to the anterior column through the inclined pedicles and in the lumbar region, where the concavity is posterior, a part of the compressive force of the anterior column is transmitted to the posterior. Thus, the compressive force in the curvilinear thoracolumbar column tends to deviate towards the line of gravity. The implications of these findings in relation to clinico-pathological disorders of the spine are discussed.

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