LUMBAR SPINE MOTION ANALYSIS IN YOUNG ADULTS

H. HAVITÇIOĞLU *   E. ALICI *   S. AKSOY *   D. ÖZAKSOY *   A. KARAKAŞLI *

ABSTRACT :

To determine the motion analysis of the normal lumbar spine, 61 of the 152 radiograps of healty young medical students in the neutral erect, active maximm flexon and maximum extensionpositions were carefully selected. Analysis of coordinates of the etension-to-flexion motion of each vertebra. In extension - to - flexion motion, the L_4 vertebra shoved a translation- predominant motion characterristic.

The L_5 vertebra had a rotation-prodominant motion characteristic.

Key Words: *Spine, motion, lumbar spine.*

INTRODUCTION :

The motion pattern for normal lumbar vertebrae and the range of motion of each vertebral vary according to the verrtebral level loads (1, 9, 10). Characteristics of the motion pattern have not been fully researched. It appears that a better understanding of the motion pattern would be beneficial to estimate various-motion segment instability.

The present study was planned to show the motion analysis of each lumbar vertebrae. The changes in the radiographic coordinates of the vertebral center, as well as the instantaneous axis of rotation (IAR), were measured. This method has been used as an index for analysis of the motion pattern of the joint of the lumbar vertebrae (4, 5, 6, 7).

For this analysis, a large number of selected radiographs of healty voluntary medical students İ(young adults) in the neutral erect, maximum flexion and maximum extewnsion positions were used.

MATERIAL AND METHODS

Lateral radiographs of 212 medical students (110 male 102 female, ranging age from 22 to 28 years) were taken in the neutral erect, active maximum flexion and maximum extension postions. The radiographs satisfying the following criteria were selected for analysis: clear and very accurate picture, no anomaly or acquired deformation in the lumbasacral region, and no pain in the lower back or legs. As a result, the optimal radiographs of 61 individuals (43 male and 18 female, ranging in age from 22 to 28 years, with a mean age of 24 yeaıs) were selected. Frontal and lateral radiographs were taken with each subject in the stationary erect position, with the position of the soles and vertex fixed. The roentgenogram tube to film distance was 175 cm, and the center of the roentgenogram tube was set at 2 cm below the umblicus. Measurement of the lInstantaneus Axis of Rotation: The IAR was measured for each of the L1 - L5 vertebrae on the basis of lateral films in the active maximum flexion, active maximum extension, and neutral erect position. The IAR for each vertebrae was determined according to Roluleaux's method (3). The IAR was defined by the upper anterior and upper posterior corners of each vertebrae. The line outlining the superior border of the lower adjoining vertebral body was defined as the x-axis: the line perpendicular to the x-axis, passing through the point that bisects the anteroposterior diameter of the vertebral body (point 0), was defined as the y-axis. The coordinates were thus obtained for the determination of the IAR for each vertebra (Fig 1a). The coordinate scales were adjusted to obtain an anteroposterior (AP) diameter of each vertebral body of 40 mm (average value of the AP diameters in 61 medical students), so that all the x and y values for the IAR obtained were also corrected.

In the lateral radiographs taken in the maximum flexion and maximum extension positions, the point of intersection of the diagonal lines of each vertebral body was regarded as the vertebral center. The vertebral center in the maximum extension position was defined as the origin of the coordinate system (point 0 in Fig 1b). The location of the vertebral center in the

* Department of Orthopaedics and Traumatology, Medical Faculty of Dokuz Eylül University İzmir - TÜRKİYE

maximum flexion position was calculated using the same coordnate system. The displacements in the direction of the x-axis and the y-axis were determined by vector analysis for the positional change in the vertebral center (Fig. 1b). The coordinates scales were also adjusted to AP diameter of the vertebral body, 40 mm, as in the correction for IAR. IAR and the vector of the vertebral center were obtained for each vertebral body by measuring from the coordinate values platted on 1-mm grid graph paper. Each analysis was carried out considering the motion from maximum extension to maximum flexion via the neutral upright position. The direction of the vector of the vertebral center was regarded as minus when both the x displacement and y displacement were minus.

Measurement of the angle of Rotation: The angle of rotation in each vertebrae was measured in the coordinate system for IAR measurement (Fig. 1a) (6, 10). The range of motion in each vertebrae was also measured by the superimposition method (2) (Fig. 1b). It can be proved by both measurements in this study and the geometrical analysis that the angle of rotation (0) is equal to the range of motion (α).

RESULTS :

Table 1 shows the coordinate values of IAR of each vertebrae in the movement from maximum extension to maximum flexion. In the L5 vertebra, the mean coordinate values of IAR were located in the first quadrant, whereas those in L4, L3, L2, and L1 vertebrae were located in the fourth quadrant. It is noteworthy that the mean coordinate values of IAR in each vertebra shoved a consistent trend. Namely, the IAR in L5 was located slightly posterior to center of the L5-S1 intervertebral disc space, and the mean IAR of L4, L3, L2, and L1 were located on a on a lower adjacent vertebrae. In particular, the y value of the IAR for the vertebrae was distincly greater than that of other vertebrae ($p < 0.001$). The x value of the IAR for the L4 vertebrae was significantly smaller than that of the L5, L2, and L1 vertebrae ($p < 0.001$). The variance of the IAR during the movement from the neutral position to maximum flexion showed a pattern similar to that during the movement from maximum extension to maximum flexion (Table 2). In contrast, the variance of the IAR during the movement from maximum extension to the neutral position showed a different pattern, and the y-value of the IAR for the L5 vertebrae was significantly greater than that for the L4 vertebrae.

Table 1. IAR coordinate Values in each vertebrae in extension - to - flexion motion

	Coordinate values of IAR	
	x-value (mm), mean + SD	y-value (mm), mean+SD
L5 (n = 61)	4.2 + 1	5.0 + 2
L4 (n = 61)	2.3 + 2	–1.6 + 1
L3 (n = 61)	3.7 + 1	–3.9 + 2
L2 (n = 61)	5.0 + 2	–4.1 + 1
L1 (n = 61)	6.1 + 2	–3.6 + 1

The changes in each vertebral center were determined by vector analysis (Table 3). Taking the range of motion (equal to the angle of rotation) into consideration together with the x andy vales, the vertebral movement, as expressed x and y, in relation to the lower adjoining vertebrae was analyzed. The results are shown in (Table 3). The absolute x value of the

Table 2. Coordinate values of IARs in each vertebrae in extension-to neutral movement and neutral-to-flexion movement.

	Extension - to - neutral		Neutral - to - flexion	
	x-value (mm), mean + SD	y-value (mm), mean + SD	x-value (mm), mean + SD	y-value (mm), mean + SD
L5	8.2 + 1	3.3	2.7 + 2	7.2 + 1
L4	8.4 + 2	–3.1	1.3 + 3	0.2 + 2
L3	9.0 + 1	–1.3	2.1 + 2	–2.8 + 2
L2	8.5 + 2	0.0	3.5 + 1	–3.6 + 2
L1	8.3 + 2	2.6 + 8	4.2 + 4	–2.6 + 1

Table 3. Displacement of the vertebral center in extension-to-flexion movement.

	Translation		
	x-value (mm) mean + SD	y-value (mm) mean + SD	Range of motion (α) degrees mean + SD
L1 (n = 61)	–6.3 + 2	–0.5 + 2	11.0 + 3
L2 (n = 61)	–8.6 + 2	–0.5 + 1	16.4 + 2
L3 (n = 61)	–9.0 + 1	0.1 + 2	16.9 + 2
L4 (n = 61)	–9.8 + 2	0.8 + 2	18.1 + 1
L5 (n = 61)	–7.4 + 1	1.5 + 1	18.7 + 2

translation was the greatest at the L4 level, followed by L3, L2, and L5 levels, with the smallest value at the L1 level. There was a significant difference in the x value between the L4 and L5 levels and between the L4 and L1 levels ($p < 0.001$). The y value during flexion showed an upward shift of 1.5 mm, on the average, at the L5 vertebrae: an upward shift of 0.6 mm at L4; an upward shift of 0 mm at L3; adownward shift of 0.7 mm at L1. The changes in the range of motion (α) was parallel ($r = 0.915$) with the y values of the vertebral center at each level. These findings suggest that, during the extension-to-flexion motion, all lumbar vertebrae, except the L3 vertebrae, show a coupling motion accompained by axial translation. The range of motion equal to the angle of rotation during the movement from maximum extension to maximum flexion was 18.7 + 2° at the L5 level, 18.1 + 2° at the L4 level, 16.9 + 2° at the L3 level, 16.4 + 2at the L2 level, 11.0 + 2° at the L1 level.

DISCUSSION :

The IAR is an axis of rotation of as rigid body when moved with respect to another fixed body, as determined by Rouleux's method (3) based on Euler's law. Therefore, the location of the IAR in presumed to reflect to relative positional changes in the vertebra in question. However, the relative motion of two adjoining vertebrae is three dimensional even during simple flexion and extension, and is accompanied by coupling. In 1988, Pearcy described the location and normal range of IAR at each lumbar vertebrae, and discussed the clinical value of IAR (7). In 1978, white stated that the location of IAR has no quantitative meaning, and can only serve as an aid in the observation of the motion pattern (10). In 1979, Panjabi clarified this using a theoretical model of IAR (6). Gertzbein took lateral radiographs of postmortem lumbar spines with degenerative intervertebral disc during movement from maximum extension to maximum flexion under an axial load, and analyzed the loci of centrode of IAR using an x-y coordinate system in whichoring was on the posteriosuperior margin of the L5 vertebrae (5). Pope et al. reported that the IAR varies in position on the motion segment, the direction of the load, load combinations, magnitude of load, and muscle activity, and this has clinical significance in terms of of ability to use the IAR as a diagnostic tool (9). From a simple diagrammatic model of IAR, the IAR can be considered a comprehensive expression of vertebral motion during flexion and extension of the spine; however this method has no quantitative meaning because of very errors in the IAR on the suboptimal radiographs (6). The mean coordinates of IAR of respective lumbar vertebrae during spinal motion from maximum extension to maximum flexion were demonstrated in (Table 3). The positional changes in each vertebral center in each vertebral center in a coordinate system, defined on the basis of the lower adjoining vertebrae, provide xuantitative numerical values that may give additional meaning to qualitative index of IAR. However, since the vertebral center shows a slight vertical shift in a coordinate system during the extension-to-flexion motion at all lumbar vertebral levels except L3, it seems that IAR should at least be regarded as an expression of the sum total of complex coupling motions. From this viewpoint, coordinate analysis of the vertebral center is considered to be a more accurate method. Thus, from the fundemental significance of the IAR and the vector analysis of the vertebral center motion, it can be summarized that during maximum flexion and extension of the lumbar spine in healthy young medical students, the translation of the L5 vertebrae is relatively minimal and the rotation is the greatest among all lumbar vertebrae. In the L4 vertebrae, translation may be greatest and rotation is moderate, and in the L3 and L2 vertebrae, translation seems to be moderate and rotation is small. Both translation and rotation of L1 vertebrae are presumed to be small.

CONCLUSION :

On the basis of the above results, it can be inferred that, during a spinal motion from maximum extension to flexion in health medical students, the L4 vertebrae shows translation-predominant movement accompanied by a slight upward shift in comparison with other lumbar vertebrae. The L5 vertebrae, however, is characterized by a rotation-predominat movement accompained by a marked upward shift.

REFERENCES :

1. Allbrook D.: Movements of the lumbar spinal column. J. Bone Joint Surg. B: 39B: 339-345, 1957.
2. Begg A.C., Falconer M.A.: Plain radiography in intraspinal protrusion of lumbar intervertebral disks: a correlation with operative findings. Br. J. Surg. 36:225-239, 1949.
3. Frankel V.H., Burstein A.H., Brooks D.B.: Biomechanics of internal derangement of the knee. J. Bone Joint Surg. (Am) 53A: 945-962, 1971.
4. Gertzbein S.D., Holtby R., Tile M., Kapasouri A., Chan K.W., Cruickshank B.: Determination of the locus of instantaneus centres of rotation of the lumbar disc by Moire fringes; a new technique. Spine 9:409-413, 1984.
5. Gertzbein S.D., Seligman J., Holtby R., Chan K.H., Kapasouri A., Tile M., Cruickshank B.: Centrode patterns and segmental instability in degenerative disc disease. Spine 10:257-261, 1985.
6. Panjabi M.M.: Center and angles of rotation of body joints; a study of errors and optimization. J. Biomech 12:911-920, 1979.
7. Pearcy M.J., Bogduk N.: Instantaneus axes of rotation of the lumbar intervertebral joints. Spine 13:1033-1041, 1988.
8. Pennal G.F., Conn G.S., McDonald G., Dale C. Garside H: Motion studies of the lumbar spine; a preliminary report. J. Bone Joint Surg. (Br) 54B:442-452, 1972.
9. Pope M.H., Wilder D.G., Matteri R.E., Frymoyer J.W.: Experimental measurements of vertebral motion under load. Orthop. Clin North Am 8: 155-167, 1977.
10. White A.A., Panjabi M.M.: The basic kinematics of the human spine. A review of past and current knowledge. Spine 3:12-29, 1978.