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Original Research Article

A STUDY OF RELATIVE MAGNITUDE OF COMPRESSIVE FORCES PASSING THROUGH THE CERVICAL AND UPPER THORACIC VERTEBRAE IN MAN

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ABSTRACT

Introduction: The vertebral bodies and intervertebral discs sustain all the vertebral compressive forces. Inferior body surface area and area of the two inferior articular facets have the quality of playing an important role in the relative magnitude of the compressive forces passing through the vertebral column through its two columns. This study has been attempted to find out the relative magnitude of the compressive forces passing through the vertebral column through its two columns so that this knowledge could be applied to explain some of the clinicopathological conditions of the spine.

Material and methods: The 6 cervical and upper 5 thoracic vertebrae of 30 human adult male columns were selected for the study. The various parameters of inferior body surface area and area of the two inferior articular facets were measured for each of the 6 cervical and upper 5 thoracic vertebrae of 30 columns.

Results: The mean inferior facet area showed a slow increase from C_2 to C_7 followed by a sharp decline at T_1 level which gradually continued to decline till T_5. The mean surface area of a single inferior articular facet area in relation to the body area showed a very slow decline from C_2 to C_7 level, but there was then a sharp decline at T_1 level and a gradual further decline to T_5 level. The percentage mean inferior body surface area showed a gradual increase from C_2 to T_5 vertebrae whereas percentage mean inferior articular facet area decreased from C_2 to T_5 vertebrae.

Conclusion: The measurements obtained by the present study reveals the importance of articular facets in understanding the mechanics of spinal anatomy and its applications.

with respect to transmission of weight. The loaded articular facet joints is one of the reason for low back pain in addition to other reasons like root pain, muscular spasm etc.

KEY WORDS: cervical vertebrae, upper thoracic vertebrae, articular facets.

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INTRODUCTION

The vertebral column in man with elaboration of appendages for locomotion is adapted to new patterns of forces in the distribution of weight [1]. The complete column of bodies and inter-vertebral discs form the central axis comparable to a pillar, which forms the main support for the bones and muscles. The adult vertebral column (also called the spine or spinal column) usually consists of 33 vertebral segments- 7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 4 coccygeal. The vertebrae can be involved in various conditions. These include fractures, infections, malignancies and inflammatory disorders [2]. Abnormal curvatures of the vertebral column in the thoracic region such as kyphosis and scoliosis may result from developmental anomalies or pathological processes involving vertebrae[3]. Almost all text books of Anatomy and many published investigations [4-6] indicate that the vertebral bodies and intervertebral discs sustain all the vertebral compressive forces. In the upper thoracic region, due to the anterior curvature, the main part of the compressive force is transmitted through the anterior column formed vertebral body and intervertebral disc, with resulting increased stress [7]. The resistance to pressure by a uniform structure depends on its cross sectional area. If one assumes that the size of a given portion of vertebra is related to the magnitude of forces acting upon it, then comparison of the size of the portion in different vertebra from the same individual should provide an assessment of the relative magnitude of those forces at different levels. Hence, this study has been attempted to find out the relative magnitude of the compressive forces passing through the vertebral column through its two columns so that this knowledge could be applied to explain some of the clinicopathological conditions of the spine.

MATERIALS AND METHODS

The present study was done on dry vertebral bones procured from the collection of Bangalore Medical College, Bangaluru, Karnataka. A total of 330 vertebrae were measured. The cervical and upper 5 thoracic vertebrae (C_2 to T_5) of 30 human adult male columns were studied in the present investigation.

To overcome personal errors in judgment, the following procedures were adopted: Initially, all the measurements were taken by the author and criteria were established till the observations made individually coincided fully. Then the observations were repeated by a double blind method. Almost all the observations and measurements which were made at the second or subsequent attempts were identical to those made at the first time a maximum difference of one millimeter. Sexing of the vertebral column was established by observing the respective pelvis including the sacrum by the criteria laid down in the text books of anatomy such as subpubic angle, ischiopubic rami, ischial spine, greater sciatic notch, preauricular sulcus, acetabular cavity, obturator foramen, ischium-pubis index, breadth and curve of sacrum, articular surface of S_1 and sacral index. Those columns in which the sex could be established unequivocally only have been included.

Adopting the various mechanical principles and ideas of Pal and Routal [4], the mean inferior body surface area and mean area of the two inferior articular facets were taken for each of the 6 cervical and upper 5 thoracic vertebrae of 30 columns.

The area of the inferior surface of the body in each vertebra was measured using graph paper method. The outline of the inferior surface of the vertebral body was, traced on to a thin tracing sheet which was then transferred on to a graph sheet with the help of a tracing paper and the area was measured in square centimeters by counting the number of squares covered. This represents the parameter of the anterior column.

The surface area of the inferior articular facets was also measured using the graph paper method. The mean area of the two sides was then calculated to obtain the mean inferior articular facet area of each vertebra.

The mean of inferior body surface Area and inferior articular facet area was calculated at each vertebral level. The results obtained were tabulated and the relative magnitude of compressive forces passing through the cervical and upper thoracic vertebrae represented by comparing percentage mean of both these parameters.

To compare the magnitude of the inferior articular facets the ratio to the inferior body surface area was calculated.

RESULTS

The area of the inferior surface of T_5 vertebra was more than double that of the body of C_2 vertebra (Table 1). The mean inferior facet area showed a slow increase from C_2 to C_7 followed by a sharp decline at T_1 level which gradually continued to decline till T_5 (Table 1). The mean surface area of a single inferior articular facet area in relation to the body area showed a very slow decline from C_2 to C_7 level, but there was then a sharp decline at T_1 level and a gradual further decline to T_5 level (Table 1). The percentage mean inferior body surface area showed a gradual increase from C_2 to T_5 vertebrae whereas percentage mean inferior articular facet area decreased from C_2 to T_5 vertebrae (Table 2). The area of the body and the two articular facets were summed and considered as the total (100%) weight bearing are from which the percentage area of the body and the two facets were calculated separately represents the percentage areas of the body and the articular facets at different vertebral levels. The posterior columns in the cervical region carried the load in the range of 32-36%, while the posterior column in the upper thoracic region carried the load in the range of 13-22% of the total weight (Table 2).

Table 1: The mean inferior body surface area, mean inferior articular facet area and ratio at each vertebral level.

Vertebral levels	Inferior body surface Area (cm2)	Inferior articular facet area (cm2)	Articular facet area Body area
C_2	2.28±0.65	0.65±0.12	0.29
C_3	2.69±0.62	0.74±0.16	0.28
C_4	3.15±0.74	0.85±0.18	0.27
C_5	3.62±0.70	0.93±0.21	0.25
C_6	4.02±0.69	0.99±0.24	0.23
C_7	4.90±0.62	1.17±0.41	0.26
T_1	5.40±0.92	0.78±0.23	0.14
T_2	5.81±1.06	0.72±0.19	0.12
T_3	5.99±1.15	0.61±0.11	0.1
T_4	6.36±1.28	0.58±0.10	0.09
T_5	6.86±1.66	0.52±0.08	0.08

Each value is Mean ± standard deviation.

Table 2: Percentage area of inferior surface of the body in comparison with inferior articular facets.

Vertebral levels	Inferior body surface Area (%)	Inferior articular facet area (%)
C_2	63.68	36.31
C_3	64.5	35.49
C_4	64.94	35.05
C_5	66.05	33.94
C_6	67	33
C_7	67.67	32.32
T_1	77.58	22.41
T_2	80.13	19.86
T_3	83.07	16.92
T_4	84.57	15.42
T_5	86.83	13.16

DISCUSSION

In the present study the magnitude of load transmission through the three columns in the cervical region and through two columns in the cervical region and through two columns in the upper thoracic region calculated on the basis of their total relative cross-sectional articular area (Table 1) suggests that transfer of load from one column to the other takes place at the junction of the cervical and thoracic curvatures. From here downward to C_7, the surface area of the two articular facets increased very little (Table 1). This suggests that load transmitted through the C_2 vertebra to the posterior columns remains constant and that the addition of extra weight at different levels in minimal.

The posterior columns in conditions of increased stress might carry even more load than that indicated by the surface area of the articular facets. The cervical column is highly mobile and hence, during movement, the distribution of weight transmission between the three columns would be constantly changing, since there is no evidence of increased stress except for the presence of mild curvature.

At the T_5 level transfer of weight from posterior to anterior column is probably, much reduced from that occurring at T_1 / T_2 is also supported by the fact that at this level there is a sharp decline in the articular facet area (Table 1). However, the bodies at the level of T_1 and T_2 do not show a proportionate increase in area as might have been expected. This suggests that the vertebral bodies in the thoracic region sustain more load than is suggested by their surface area.

This increase in stress is due to the anterior curvature. Hence in the upper thoracic region a major proportion. According to the study of Pal and Routal [4] a similar trend was observed in their study of the cervical and upper thoracic vertebrae (Table 3). Denis [8] and Louis [9] are of the opinion that throughout the vertebral column, zygopophysial joints play an important role in weight bearing. Denis [8] on the basis of his "three column spine" concept states that the facet joints and posterior ligamentous complexes are involved in conferring stability on the vertebral column. Dhall [10] was of the opinion that the size of the articular facet is correlated with the magnitude of stress imposed on them.

Table 3: Comparison of inferior articular facet area, inferior body surface area and ratio with other studies [4].

Vertebral level	Inferior body Surface area		Inferior articular facet area		Inferior articular facet area/Inferior body surface area	
	Study of Pal & Routal	Present study	Study of Pal & Routal	Present study	Study of Pal & Routal	Present study
C_2	2.41	2.28	1.02	0.65	0.42	0.29
C_4	2.75	3.15	1.05	0.85	0.38	0.27
C_6	3.28	4.02	1.16	0.99	0.35	0.25
C_7	3.69	3.25	1.19	1.06	0.32	0.23
T_1	4.25	5.4	0.98	0.78	0.23	0.14
T_2	4.76	5.81	0.9	0.72	0.18	0.12
T_5	5.34	6.86	0.83	0.52	0.15	0.08

The interpretation of the mean inferior articular facet area / mean inferior body surface area ratio in thoracic region is misleading when analysed alone. Hence, inspite of the gradual increase in mean inferior articular facet area, the ratio of these measurements to inferior body surface area, show a gradual decrease, these again suggest that at each level, the load brought by the ribs to the laminae or inferior articular facets is transmitted to the anterior column.

In our study of 30 columns, the mean inferior body surface area showed a gradual increase from above downwards. The area of the inferior surface of T_5 vertebra was almost more than double that of the body of C_2 vertebra. The mean surface area of the inferior articular facet showed a slow increment from C_2 to C_7 followed by a sharp decline at T_1 level which continued to T_5. On the basis of the above measurements the compressive forces in the cervical region, the posterior column carried a load in the range of 32 to 36% while in the upper thoracic region it was 13-22%. The range was lower in the present study which may be due to the ethnic differences in the people involved in the study.

CONCLUSION

The present study had observed maximum area for inferior articular facets at C_7; as inferior articular facets at C_7 will form zygapophyseal joint with superior articular facets of T_1. Thus the relative magnitude of compressive forces of articular facets passing through the vertebral column plays an important role in weight transmission through the spine. Hence in construction of model of spine to the study the effects of injury and surgery on spine huge sample size of spinal columns should be taken into account for measurements of articular facets which the present study had managed by providing parameters of articular facets of 30 spines (330 vertebrae). The measurements obtained by the present study reveals the importance of articular facets in understanding the mechanics of spinal anatomy and its applications with respect to transmission of weight. The loaded articular facet joints is one of the reason for low back pain in addition to other reasons like root pain, muscular spasm etc.

Conflicts of Interests: None

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