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Original Article

MORPHOMETRIC AND MORPHOLOGICAL STUDY OF ARTICULAR FACETS OF THE THORACOLUMBAR VERTEBRAL COLUMN IN NORTH INDIAN POPULATION

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ABSTRACT

Background: The articular processes of thoracolumbar vertebral column play an important role in weight transmission and determining the range and direction of movements between any two vertebrae. Size of these facets has been correlated with the magnitude of stress imposed on them.

Purpose of study: The present study has been conducted on the articular processes of 510 vertebrae (thoracic: 360; lumbar:150) with the aim to provide high quality data sets for constructing the models of spine to study mechanics of spinal instrumentation. The length , width and the distance between the right & left superior & inferior articular processes have been measured with the vernier callipers. The presence/ absence of mamillary tubercle has been observed in the present study.

Results: The length of thoracic SAFs was almost same at all levels whereas that of the lumbar SAFs increased gradually from L1-L5. However the width showed a variable trend. In case of thoracic IAFs both these parameters showed a variable trend. Whereas in lumbar region, these increased gradually from L1-L5. The distance between two inferior articular processes was more than that between two superior articular processes at almost all levels except T1-T3 & L1-L4 where reverse was true. The mamillary tubercle/process was altogether absent from T-1 to T-8. From T-9 to T-11, the number of vertebral column showing mamillary tubercle increased from 4-19. However at T-12, it was seen in 29 Vertebral columns. In lumbar region, it was well developed in all vertebrae and termed as mamillary process.

Conclusion: The measurements obtained by present study reveals the importance of articular facets in understanding basic spinal mechanics and its application with respect to weight transmission.

KEY WORDS: Superior articular facet, Inferior articular facet, Mamillary process, weight transmission.

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INTRODUCTION

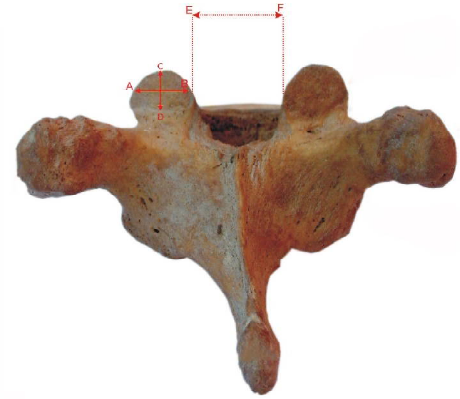
The articular processes of thoracic & lumbar vertebrae not only play a pivotal role in weight transmission through vertebral column but also determine the range and direction of movements. In thoracic region, the superior articular processes are nearly circular & their surfaces are flat. These project upward from pediculolaminar junction directed posterolaterally whereas in lumbar region, these bear vertical concave articular facets directed posteromedially, with a rough mamillary process on their posterior borders. The inferior articular processes, in thoracic region, bear oval & concave facet directed forwards, slightly downwards & medially [1,2,3]. In lumbar region, these have convex articular facets facing anterolaterally so that they look away from each other [2]. In thoracic region, lack of upward inclination of SAFs prohibits much flexion & extension. However, the direction of articular facets allow free rotation, [4]. The lumbar extension is wider in range than flexion while the rotation is limited by absence of common centre of curvature for right & left articular facets [5]. The zygapophyseal / facet joints are extremely important in the biomechanical & clinical behaviour of the spinal column [6]. These have been related to frequent source of low back pain [7,8,9]. Dhall (1984) [10] correlated the size of articular facets with the magnitude of stress imposed on them. Goel et al,1988 [11] used the models of spine to study the mechanics of spinal instrumentation. Considering the importance of thoracic & lumbar articular facets in clinical setting and in understanding basic spinal mechanics, the present study was designed to provide high quality data sets of these articular facets.

MATERIALS AND METHODS

The present study was conducted at Govt Medical college, Amritsar after getting approval from Institutional Ethical Committee. The material for the study comprised of 30 adult human male thoracolumbar vertebral columns i.e. a total of 510 vertebrae (thoracic:360 & lumbar: 150) obtained from department of Anatomy, Govt Medical college, Amritsar. The vertebrae were without any gross abnormality. These were labelled from T1 to L5 depending on the vertebra & bound in a wire in the correct sequence. Any particular set of column was belonging to the same body. Different parameters of superior (SAFs) & inferior articular facets (IAFs) (vide infra) were measured with the help of a vernier calliper with least count of 0.02mm and mamillary tubercles were observed.

Length of SAF: It was measured with vernier callipers on both sides as the vertical distance between the most superior point to the most inferior point on the facet at their centre. (CD in fig 1)

Fig. 1



AB: Width of superior articular facet,
CD: Length of Superior articular facet,
EF: Distance between two superior articular processes.

Width of SAF: It was measured with vernier callipers on both sides as the horizontal distance in the centre of the facet. (AB in fig 1)

Distance between the two superior articular processes: It was measured with vernier callipers as the distance between the medial borders of the right and left superior articular processes (EF in Fig1).

Length of the inferior articular facet: It was measured with vernier callipers as the vertical distance between the most superior to most inferior point on the facet almost at its centre on both sides. (AB in Fig.2).

Fig. 2

AB- Length of the articular facet.

Width of the inferior articular facet: It was measured with vernier callipers as the horizontal distance on the facet almost in its centre on both sides (AB in Fig3).

Distance between two inferior articular processes: It was measured with vernier callipers as the distance between the medial borders of right and left inferior articular processes. (CD in Fig.3).

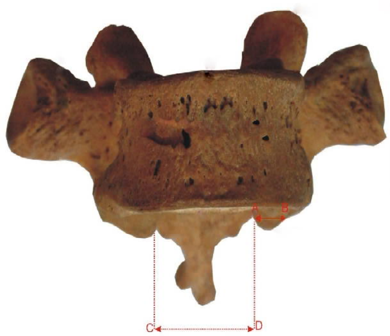


Fig. 3

AB- width of inferior articular facet.
CD: Distance between two inferior articular facets.

Mamillary tubercle/ process: The lower thoracic and all lumbar vertebrae were examined for the presence/absence of a rough elevation on the posterior border of the superior articular process called as mamillary tubercle/ process on both the sides [12].

RESULTS

Table 1 shows the length & width of SAF on right & left sides and also the distance between the two superior articular processes. It was observed that the length of SAF was almost same at all thoracic levels ranging between 10-11mm on both the sides. However, in lumbar region, it increased gradually from L1 (R:12.32mm; L: 12.42mm) to L5 (R:15.31mm; L: 15.65mm). On comparing the length on two sides, it was found to be more on right side by 0.02mm at all thoracic levels whereas it was more on left side by 0.04-0.34 mm at all lumbar levels. The width, on right side, first decreased from 11.45mm at T1 (Range: 6.16-17.17mm) to 9.67mm at T8 (Range: 7.74- 13.10mm) with a slight crest seen at T5. Thereafter, it increased to 15.43mm at L5 (Range: 8.40-21.76mm) with a dip seen at T12. On left side, it first decreased from 12.58mm at T1 (Range: 8.00-21.37mm) to 9.89mm at T3 (Range: 7.54-11.34mm). Thereafter, it increased to 15.21mm at L5 (Range: 8.00-20.84mm) with almost same values seen in mid-thoracic region (T4-T8) and 2 dips seen at T11 & T12. When it was compared on two sides, it was found to be more on left side at all levels by 0.01-1mm except T2-T5 & L5 (more on right side by 0.07-0.6mm). The distance between the two superior articular processes first decreased from 17.90mm at T1 (Range:12.25-27.02mm) to 10.98mm at T6 (Range:5.00-17.63mm). There after, it increased to 20.90mm at L5 (Range:13.05-28.83mm) with a slight dip seen at T11. No comparative data was available in the accessible literature.

Mamillary Tubercle/ process: In the present study, mamillary tubercle was absent altogether from T1-T8 on both sides. As we moved caudally, at T9, it was encountered bilaterally in 4 (13.33%); at T10, in 15 (50%); at T11, in 19 (63.33%) and at T12, in 29 (96.67%) vertebral columns. From T9-T11 it was directed posterosuperiorly from the root of the transverse process. However, at T12, it was projecting superomedially. In lumbar region (L1-L5), this tubercle was found to be present bilaterally on the posterior border of the superior articular process of all the vertebrae and was more prominent and distinct being called as mamillary process.

lumbar region, it increased consistently from L1 (R:10.86mm; L:10.81mm) to L5 (R:14.09mm; L:14.01mm) on both sides. When compared on two sides, it was found to be more on right side at most of the levels by 0.01-0.4mm except T2, T5, T9, T11 & L2 where it was more on left side by 0.01-0.35mm. Length was also compared with width of IAF & it followed the same pattern as was seen in case of SAF. The distance between two inferior articular processes first decreased from 15.29mm at T1 (Range: 11.14-24.20mm) to 11.96mm at T7 (Range: 11.14-24.20mm) with a crest seen at T4. Thereafter, it increased to 23.53mm at L5 (Range: 15.08-33.77mm) with a slight dip seen at L1. Distance between two superior articular processes & two inferior articular processes were also compared. It was seen that the distance between two inferior articular processes was more than that between two superior articular processes at almost all levels. No comparative data was available in the accessible literature.

DISCUSSION

All the parameters were compared with the previous studies done by various authors on different population (see table 1 & table 2). It was observed that the length of SAF was in consonance with Masharawi et al [13] who categorically found it of same size in thoracic region but increasing sharply & continously in

Table 1: Showing The Length And Width Of Superior Articular Facet & Distance Between Two Superior Articular Processes.

Parameter		Length of superior articular facet				Width of superior articular facet				Distance b/w 2 superior articular processes	
Author		Panjabi et al. 1993 [14]	Patel et al. 2007 [15]	Present Study		Panjabi et al. 1993 [14]	Patel et al. 2007 [15]	Present Study		Present study	
Population		Western	Indian	North Indian		Western	Indian	North Indian		North Indian	
(mm)		Mean	Mean	Mean	Range	Mean	Mean	Mean	Range	Mean	Range
T1	R	12.6	9.3	10.15	5.44-15.00	12.3	13.3	11.45	6.16-17.17	17.9	12.25-27.02
	L	12.6	9.67	10.13	7.11-14.81	14	13.41	12.58	8.00-21.37		
T2	R	12.2	9.85	10.87	8.07-15.83	11.7	10.48	11.39	8.12-19.25	15.81	8.05-24.25
	L	13	10.22	10.81	8.77-14.15	12.1	10.52	11.15	7.56-14.77		
T3	R	10.8	9.52	10.62	8.20-13.58	10.8	9.8	10.41	7.39-16.03	12.91	5.55-19.76
	L	11.7	10.48	10.5	7.86-12.93	10.6	9.56	9.89	7.54-11.34		
T4	R	10.8	14.71	10.85	7.47-14.71	10.5	9.5	10.14	8.15-13.03	12.6	5.50-20.54
	L	11.5	9.25	9.92	6.73-12.06	10.3	9.17	10.07	8.02-12.56		
T5	R	12.1	8.96	11.05	8.64-14.32	10.6	9.44	10.58	8.80-14.26	12.09	5.61-19.14
	L	10.9	9.24	10.2	6.68-13.37	9.8	8.64	9.97	8.31-12.85		
T6	R	11.7	9	10.49	8.05-13.23	9.6	8.96	9.88	7.54-14.21	10.98	5.00-17.63
	L	11.8	9.15	10.33	7.14-13.36	10.1	8.58	9.99	8.30-12.33		
T7	R	11.9	8.78	10.72	7.75-15.68	9.6	8.56	9.98	6.22-15.74	11.04	5.1-16.6
	L	11	9.11	10.31	6.83-13.56	9.9	8.74	10.06	8.18-15.91		
T8	R	11.5	8.63	10.29	7.68-14.00	10	8.74	9.67	7.74-13.10	11.3	7.26-15.86
	L	11.7	9.07	10.22	5.87-11.24	10.3	8.78	10	7.54-12.78		
T9	R	12.1	8.62	11.17	8.13-16.54	11	9.04	10.36	5.65-15.63	11.42	7.32-16.56
	L	11.7	9.12	10.67	7.36-14.68	10.7	8.5	10.56	7.35-14.73		
T10	R	12	8.76	11.26	8.50-14.12	11.5	9.68	11.21	8.20-15.02	11.51	7.09-15.5
	L	12.4	9.16	11.13	8.77-14.24	12.9	9.52	11.57	8.33-16.71		
T11	R	12.5	9.32	11.1	8.99-13.72	11.4	10.08	11.24	7.84-16.46	11.36	6.47-15.82
	L	12	9.52	10.98	7.00-13.40	11.3	9.88	11.4	8.55-14.98		
T12	R	13.4	9.42	11.61	7.23-15.10	11.2	9.29	10.88	7.89-14.74	14.62	8.48-19.04
	L	12.5	9.84	11.19	6.72-15.27	10.5	9.16	10.89	7.91-14.50		
L1	R	12.7	10.33	12.32	7.02-17.38	10.2	10.25	11.63	6.62-15.68	17.16	12.60-20.89
	L	12.2	11	12.42	9.22-15.96	10.5	11	11.82	7.62-15.54		
L2	R	14.6	11.85	13.82	8.42-22.02	11.1	13.04	12.69	6.71-18.92	17.65	12.84-21.21
	L	14.6	12.46	13.91	9.95-20.29	11.4	13.31	12.85	7.81-18.20		
L3	R	16	12.69	14.62	8.40-20.79	13.8	13.85	14.21	7.26-19.43	17.98	12.41-22.54
	L	15.9	12.77	14.66	11.0-19.99	13.9	13.92	14.44	8.43-18.68		
L4	R	16.1	12.77	15.22	10.4-22.73	14.1	15.04	14.73	9.10-20.45	18.9	13.70-24.50
	L	17.3	12.85	15.46	10.9-22.67	15.3	14.96	14.82	9.23-19.12		
L5	R	17.4	12.85	15.31	10.6-21.53	16.3	15.2	15.43	8.40-21.76	20.9	13.05-28.83
	L	17.5	13.2	15.65	9.84-22.71	14.9	15.1	15.21	8.00-20.84		

Table 2 shows the length & width of IAF on right & left sides and also the distance between the two IAFs. It was observed that the length, in thoracic region, on both sides, did not follow a regular trend & varied between 10.30-12.40mm. However, in lumbar region, it increased almost constantly from L1 (R:14.17mm; L:14.00mm) to L5 (R:16.42mm; L:16.24mm). On comparing both sides, it was seen to be more on left side at most of the levels by 0.05-0.65mm except T4, T11-L2 & L5 where it was more on right side by 0.03-0.7mm. Like length, the width also did not follow any regular trend in thoracic region on both sides & varied between 9.58-11.83mm. However, in

Table 2: Showing The Length, Width Of Inferior Articular Facet And Distance Between Two Inferior Articular Processes.

Parameter		Length of inferior Articular facet				Width of inferior Articular facet				Distance b/w 2 inferior articular processes	
Author		Panjabi et al. 1993 [14]	Patel et al. 2007 [15]	Present study		Panjabi et al. 1993 [14]	Patel et al. 2007 [15]	Present Study		Present Study	
Population (mm)		Western	Indian	North Indian		Western	Indian	North Indian		North Indian	
(mm)		Mean	Mean	Mean	Range	Mean	Mean	Mean	Range	Mean	Range
T1	R	12.5	9	10.91	7.72-14.42	11.9	9.71	11.46	8.68-18.26	15.29	11.16-24.20
	L	13.3	9.31	11.46	7.45-15.34	13.2	9.88	11.09	8.25-15.16		
T2	R	11.2	9.09	10.89	8.54-13.80	11.1	9.22	10.38	7.87-14.73	14	10.22-19.30
	L	11.8	9.09	11.26	8.76-14.68	11	9.28	10.53	9.00-11.82		
T3	R	11	8.67	10.53	8.21-12.72	9.9	8.96	9.97	7.87-12.42	12.57	8.25-16.4
	L	10.7	8.63	10.53	8.17-12.69	10.4	8.85	9.96	8.29-11.59		
T4	R	11	8.77	10.85	7.95-15.20	10.4	8.73	10.04	8.06-12.81	12.71	8.24-16.78
	L	11	8.67	10.82	8.67-14.60	9.8	8.57	9.63	8.20-11.77		
T5	R	10.9	8.31	10.4	8.30-13.70	9.7	8.16	9.89	8.02-14.46	12.39	8.64-16.62
	L	11.2	8.28	10.77	8.28-15.03	9.7	8.13	10.23	7.94-15.86		
T6	R	10.3	8.21	10.31	7.98-13.87	9.6	8.21	9.94	8.21-13.85	12.14	9.07-15.15
	L	11.1	8.33	10.7	8.33-14.82	9.7	8.18	9.87	7.83-13.68		
T7	R	10.6	8.26	10.57	8.26-13.02	9.8	8.24	10.4	8.24-15.03	11.96	8.95-15.00
	L	11	8.24	10.84	8.24-13.11	10.3	8.18	10.39	8.18-13.71		
T8	R	10.9	8.18	10.73	8.18-14.50	10.4	8.33	10.33	7.94-14.32	12.13	8.28-15.58
	L	11.6	8.39	11.09	8.39-14.68	10.7	8.36	10.28	8.16-14.00		
T9	R	12.3	9	11.78	9.00-16.21	11.9	9.36	11.64	7.99-15.28	12.25	8.42-15.97
	L	12.5	9	12.09	8.51-16.18	12.6	9.48	11.7	7.73-15.53		
T10	R	12.4	9.5	11.63	8.55-14.46	11.9	9.63	11.83	9.01-16.38	12.31	8.00-17.45
	L	11.7	9.6	12.28	9.15-17.29	11.4	9.67	11.64	9.58-15.70		
T11	R	13.3	9.5	12.44	8.14-15.69	11.4	9.4	10.33	5.81-14.37	13.93	9.90-18.51
	L	12.5	9.63	11.73	8.35-15.12	10.9	9.43	10.42	7.31-16.38		
T12	R	12.5	9.97	12.32	8.88-15.59	9.5	9.5	9.58	6.53-12.66	15	10.00-18.65
	L	12.7	9.93	12.02	8.77-17.25	9.8	9.47	9.58	7.28-12.70		
L1	R	15.3	11.27	14.17	8.34-21.35	12.4	10.6	10.86	7.61-14.26	14.93	11.60-19.36
	L	15.2	11.37	14	9.19-19.87	10.7	10.77	10.81	7.60-13.72		
L2	R	16	12.47	15.01	11.70-22.14	12.7	10.63	11.51	7.35-14.10	15.73	11.98-21.23
	L	16.3	12.53	14.39	11.10-21.10	12.2	11.81	11.52	6.81-15.51		
L3	R	15.7	12.77	15.24	10.56-20.16	13.8	12.33	11.87	6.90-15.66	16.09	10.88-19.86
	L	16.4	12.9	15.57	10.83-20.48	13.4	12.43	11.85	7.00-15.00		
L4	R	16.2	12.83	15.38	11.48-22.61	14.7	12.97	13.07	7.28-18.45	18.3	10.88-26.25
	L	15.6	12.9	15.43	11.00-20.93	14.1	12.83	12.9	7.10-17.94		
L5	R	18.4	13.13	16.42	11.94-22.66	15.6	13.61	14.09	7.04-19.76	23.53	15.08-33.77
	L	17.3	13.23	16.24	11.32-21.86	16.1	13.58	14.01	7.40-18.21		

lumbar region. However, in our study, the SAFs were longer on right side in thoracic region and on left side in lumbar region which was in contrast with Masharawi et al [13] who found it longer on left side in thoracic & on right side in lumbar region. When compared with western population [14] it was found to be less in North Indians at all levels by 0.2-2.5mm which may be due to the fact that the average height of western population is greater than Indian population. However, it was more in North Indians at almost all levels by 0.4-2.6mm as compared with Indian population of other regions [6,15] which may be attributed to regional variations. Like length, the width in North Indians was less at almost all levels by 0.3-1mm as compared with western population [14] & more by 0.2-2mm as compared with Indian population of other regions [6,15] due to same reason. Length & width of SAF were also compared with each other. It was seen that the length was more than the width of SAF at almost all levels by 0.16-

1mm on both sides. This was in consonance with Panjabi et al[14] and Masharawi et al [13]. However, Patel et al [15] found the width to be more as compared with height in upper thoracic & lumbar regions.. Similar variation was observed for the IAFs. The length of IAF was found to be less in North Indians at all levels by 0.03-2mm as compared with Western population [14]. However, it was more in North Indians at all levels by 1.8-3.3mm as compared with Indian population of Gujrat state [15]. The width of IAF was found to be less in North Indians at all levels by 0.07-2.1mm as compared with Western population [14]. However, it was more in North Indians at all levels by 0.04-2.30mm as compared with Indian population of Gujrat state [15]. The differences may be attributed to racial, regional & ethnic variations. No comparative data was available in the accessible literature for the distance between two superior articular processes and two inferior articular processes.

The morphology of mamillary tubercle/ process was in consonance with Pal & Routal [16] who observed fusion to a varied extent between the superior articular process and mamillary tubercle at T12 and L1. Pal & Routal [16] revealed that due to the gradual rotation/ sagittalisation, the superior articular process comes close to the mamillary tubercle which fuses with it to form the lumbar like superior articular process. This fusion starts from below and proceeds upwards, as a notch of varying depth is observed between the 2 processes in a few vertebrae. They further speculated that because of fusion, the articular surface gradually extends over the medial aspect of the mamillary tubercle. Thus, the posterior most part of the lumbar superior articular process is formed by the fused mamillary tubercle which, morphologically, is an integral part of the transverse process.

Functional Significance: The articular facets play an important role in weight transmission through the spinal column. According to Pal & Routal,1987[17] the mechanism of weight transmission in the thoracic & lumbar region of vertebral column depends upon the following three factors:

(i) Zygapophyseal joints are involved in weight bearing and a considerable proportion of weight is transmitted through lumbar facet joints.

(ii) Forces act at right angles to the plane of any articular surface.

(iii) Line of gravity passes anterior to the vertebral bodies in thoracic region (because of thoracic kyphosis) and posterior to them in lumbar region (because of lumbar lordosis) crossing the column at T11 and T12 vertebral level.

As the thoracic column is concave anteriorly and the line of gravity passes anterior to the vertebral bodies, there is tendency for accentuation of load on the vertebral bodies. Hence the weight acting at the zygapophyseal joints is also transmitted towards the vertebral body. This is supported by the fact that the superior articular surface faces posterolaterally and thus would transmit the weight anteromedially to the body through its pedicles (See Fig.4). In the lumbar region the line of gravity passes posterior to the vertebral bodies; there is therefore a tendency for weight to be accentuated on the zygapophyseal joints. The posteromedially facing curved articular surface of the lumbar vertebrae is excepted to receive the load from the inferior articular process of the upper vertebra and transmit it to anterolaterally to its strong wall (See Fig.5). From the superior articular process this load is transmitted inferiorly to the lamina. The superior articular processes in the lumbar region are curved because they have to embrace the inferior articular processes intimately to receive the load and then to transmit it below to the lamina.

Fig. 4: Diagrammatic representation of a typical thoracic vertebra seen from above. From the lateral part of articular surface forces are transmitted to the pedicle (a), whereas from medial part forces are transmitted below to the lamina (b)

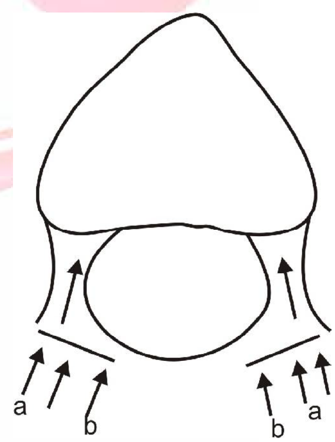
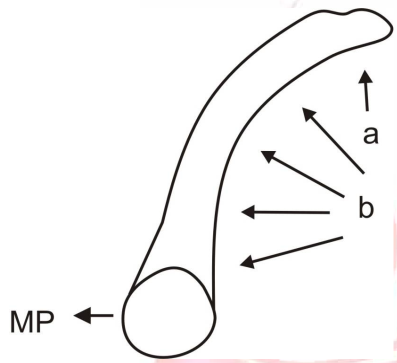


Fig. 5: Diagrammatic representation of a transverse section passing through a typical lumbar superior articular process. Forces act at right angle to articular surface. The articular surface facing dorsally transmits the load to the pedicle (a) and a large surface facing medially transmits the forces laterally to the superior articular process (b). MP: mamillary Process. From the superior articular process the forces converge to be transmitted to the inferior articular process.



The above mechanism of load transmission by the lumbar facet joints is also supported by the findings of Cihak [18], according to whom the lumbar zygapophyseal joints, at birth, are all oriented in the coronal plane, similar to the joints of thoracic vertebrae. However, during the postnatal growth their orientation starts to change from coronal to sagittal plane. The process of 'sagittalisation' begins at the 6th postnatal month and is completed by the age of 18 months. During this period the articular surface gradually rotates from coronal to sagittal, becoming characteristically curved at the same time. From the above findings of Cihak [18], it may be said that the period of sagittalisation corresponds to the development of lumbar curvature which is associated with the child learning to stand erect and walk. Thus the process of sagittalisation of the articular processes in lumbar region is associated with loading of the zygapophyseal joints. The sagittally oriented curved articular processes are well adapted to bear the load acting at the lumbar zygapophyseal joints. Further,the fusion between the superior articular & mamillary processes in the lumbar region is an important functional adaptation to receive the weight from the vertebra above.

SUMMARY & CONCLUSION

To summarise, in case of SAF, the length was almost same at all thoracic levels but increased gradually from L1 to L5. The width depicted a variable trend. The distance between two superior articular processes first decreased from T-1 to T-6 and then increased to L-5 with a slight dip at T-11. The mamillary tubercle/process was altogether absent from T-1 to T-8. From T-9 to T-11, the number of vertebral column showing mamillary tubercle increased from 4-19. However at T-12, it was seen in 29 Vertebral columns & projecting superomedially. In lumbar region, it was well developed in all vertebrae known as mamillary process.

In case of IAF, in thoracic region, neither length nor width of IAF depicted any trend but in lumbar region, both these parameters increased from L1 to L5. The distance between two inferior articular processes first decreased from T1 to T7 with a crest seen at T4 and thereafter it increased to L5 with a slight dip at L1.

The distance between two inferior articular processes was more than that between two superior articular processes at all levels except T1-T3 & L1-L4 where reverse was true.

Conflicts of Interests: None

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