

Functional Radiographic Diagnosis of the Cervical Spine: Flexion/Extension

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The cervical spines of 59 adults were examined by means of functional roentgenograms. They were divided into two groups consisting of 28 healthy adults and 31 patients who had sustained soft tissue injury to the cervical spine and who were complaining of neck pain. Roentgenographic lateral views were taken in active flexion and extension as well as in passive maximal flexion and extension. Measurements using the techniques of Penning and Buetti-Bäumli were made by three observers independently. There was a highly significant difference between the active and passive segmental ranges of motion in healthy adults. Based on the normal values obtained in this study, 19 hypermobile segments could be diagnosed during the active examination, while 31 hypermobile segments were found during the passive examination. In addition, the active examination found 60 hypomobile segments, while the passive examination showed only 43 hypomobile segments. The Penning Method of measurement was found to be more reliable than that of Buetti-Bäumli. If possible, the functional roentgenogram examination of the cervical spine in the sagittal plane should be performed by including passive movement and the range of motion should be compared with the normal values obtained by passive examination. [Key words: cervical spine, functional roentgenograms, instability, technique of measurement, injury]

ACCORDING TO THE ORIENTATION of the intervertebral joints, the predominant movement of the segments below C2 is flexion/extension, or rotation about the x-axis in the three-dimensional coordinate system.^{4,5,7,11} The almost horizontally oriented atlanto-axial joints determine the dominant movement of axial rotation, or rotation about the y-axis at that level.^{4-7,10} The most important tools for the study of the functional spinal unit for different regions of the cervical spine are the X-ray-motion-studies, in brief called Functional Radiology. The most accurate measurements of axial rotation of the upper cervical spine preferably are obtained by using functional computed tomography (CT) scans.^{4,6} The upper cervical spine also can be evaluated functionally by sidebending roentgenograms.⁹

Radiologic studies of flexion-extension motion of the middle and lower cervical spine were performed by Bakke,¹ De Seze et al,³ Buetti-Bäumli,² and Penning.⁷ Table 1 summarizes the established

normal values of segmental motion based on different original papers. Most notably, the monographs of Buetti-Bäumli² (1954) and Penning⁸ (1960) presented for the first time the normal values of segmental motions. Buetti-Bäumli developed the Designation Movement Diagram. It shows one vertebra in a fixed position and the adjacent cranial vertebra in a position of flexion and extension. The angle of the lines drawn along the posterior border of the "moving" vertebra in its two end-positions represents the degree of flexion-extension motion. An example of the technique of measurement on a patient in this study is shown in Figure 1. The average values (Table 1) of the segmental movement in his study were based on 28 healthy adults.

In 1960, Penning⁸ designed a new, less time-consuming method for determining the flexion/extension of motion. The extension film is superimposed on the flexion film, with the C7 vertebrae exactly matching. A line is drawn along one of the edges of the flexion film onto the extension film. Next C6 is superimposed and a second line is drawn. The angle between the two lines is the degree of flexion-extension movement between C6 and C7. In the same way, the range of motion between the other vertebrae is determined. Figure 2 shows an example of this technique of measurement. Also, Penning established average values of segmental motion, based upon the examination of 20 normal healthy adults.

However, these valuable original reports of the analysis of flexion-extension motion of the cervical spine imply certain disadvantages. Bakke drew lines on the radiographs along upper and lower end-plates of the vertebral bodies and calculated the degree of motion from differences in the angle between these lines in flexion and extension.¹ Buetti-Bäumli used lines drawn along the posterior borders of the vertebral bodies in order to measure the degree of motion.² A problem occurs when the vertebral end-plates and posterior borders are not straight, making the positions of the lines to be drawn somewhat arbitrary. Moreover, the use of auxiliary lines, as suggested by both authors, is time-consuming and hence unsuitable for routine practice. The method presented by Penning⁸ does not have this disadvantage. To avoid the problem of dark films that cannot be superimposed Penning proposed exposing the extension image on a reverse film.

Based upon the knowledge of clinical biomechanics, and knowing that there is definitely a difference between the actively and passively induced movement in any joint, the limitations of all of the previous studies can be surmised. All of the previous examinations have been performed by measuring the difference between flexion and extension during active movement only.

By analyzing the functional radiographs of active motion of patients, one is dependent on the collaboration of the patient, who usually is suffering from some degree of pain. This increases the possibility of missing evidence of hypermobility or instability.

Since the functional radiographs in flexion and extension motion of the cervical spine are widely used in Europe, we designed the present study in order to compare the actively and passively

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Table 1. Summary of the Normal Values Established by Different Authors

	Bakke 1931	Buetti-Bauml 1954	De Seze 1951	Penning 1960	Dvorak/Froehlich 1987
C1-C2	11.7				12
C2-C3	12.6	11	13	12.5	10
C3-C4	15.4	17	15.5	18	15
C4-C5	15.1	21	19	20	19
C5-C6	20.4	23	27.5	21.5	20
C6-C7	17.0	19	17.5	15.5	19

There is a large spread of normal mobility in each segment.

performed flexion and extension of the cervical spine on lateral roentgenograms.

RESEARCH QUESTIONS

- 1) Which particular technique of measurement, that described by Buetti-Bäuml (1957) or that described by Penning (1960), is more reliable and suitable for the routine examination?
- 2) Is there a significant difference in the ranges of motion obtained by active and passive movements (in healthy adults)?
- 3) How does the passive examination alter the results in injured patients as related to segmental hypo- and hypermobility?

METHODS

Examined Population. Twenty-eight healthy adults and 31 patients who had suffered soft tissue injuries of the cervical spine have been examined. In the same visit, the active and passive flexion-extension roentgenograms in the lateral view were obtained. Excluded from the study were all patients with suspected fractures or congenital malformations, as well as all patients with inflammatory diseases such as rheumatoid arthritis.

Technique of the Roentgenogram Examination. The subjects were standing in an upright position. The left side of the body was closer to the film. The distance between the film and x-ray tube was 150 cm. The head was in neutral position, the shoulders hanging down as low as possible in order to show the cervical-thoracic junction. With two fixing pellets, the mid-thoracic spine and the sternum were fixed in order to avoid flexion-extension of the thoracic spine (Figure 3A). The subjects were asked to bend the

head forward as much as possible and a film was then taken (Figure 3B). In the next step, an active extension was performed and another film was taken in this position (Figure 3C).

All passive examinations were performed by the first author. The examiner was wearing a whole lead coat with long sleeves, and lead gloves as well as lead glasses. During passive examination, the examiner placed his left hand on the back of the patient's head (Figure 4A), the right hand first holding the patient's chin, and inclination at C1-occiput was induced, followed by maximal flexion. Extension was then induced by holding the head with the right and the chin with the left hand (Figure 4B).

Patients suffering from motion-induced pain of the cervical spine received an oral analgesic (paracetamol 1000 mg) 1 hour before the examination.

Technique of Measurements. All active and passive functional roentgenograms were measured by using the original Buetti-Bäuml method² as described previously (Figure 1). The original Penning method⁸ (Figure 2) was modified by using reverse films for the extension movement. This allowed a more precise superposition of each vertebra during flexion and extension. Three independent observers were used in this study. For any particular method of measurement, only two independent observers were used. All functional roentgenograms of the healthy volunteers and patients were measured using both methods. To ensure the independence of the measurements, a set of copies was provided to each observer.

Statistical Analysis. The data were stored in the Macintosh SE and processed using the EXCEL Program. The statistical analysis was performed by using Student and chi square distributions.

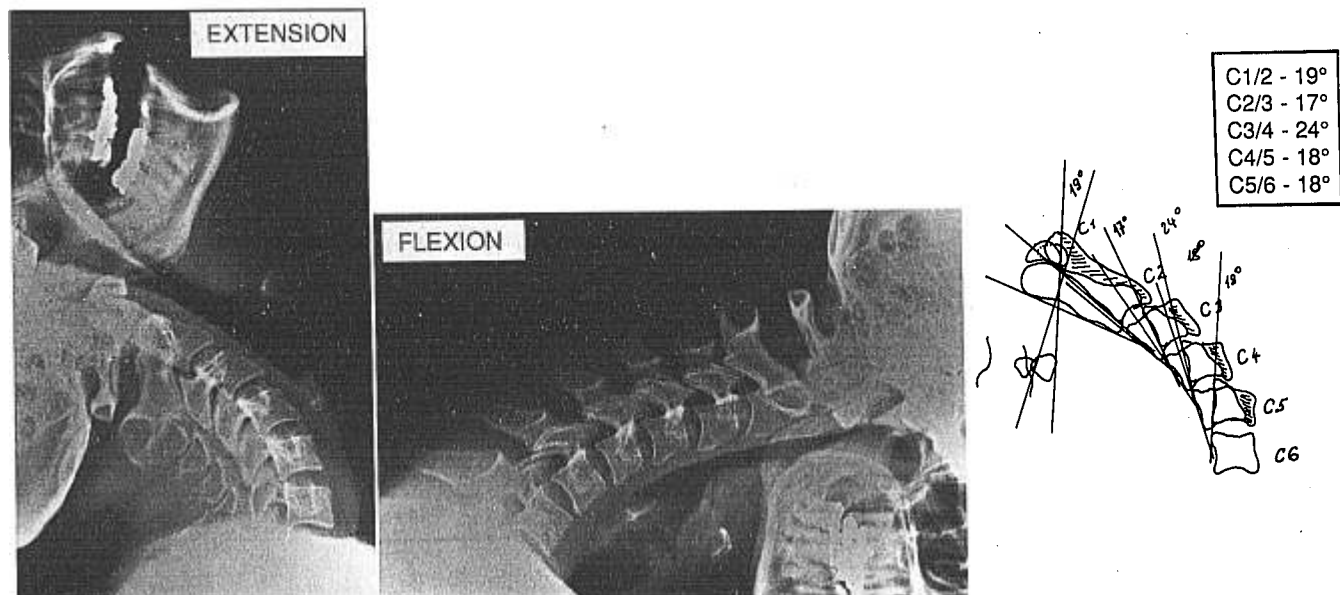


Fig 1. Example of functional diagram according to Buetti-Bäuml, technique of measurement.

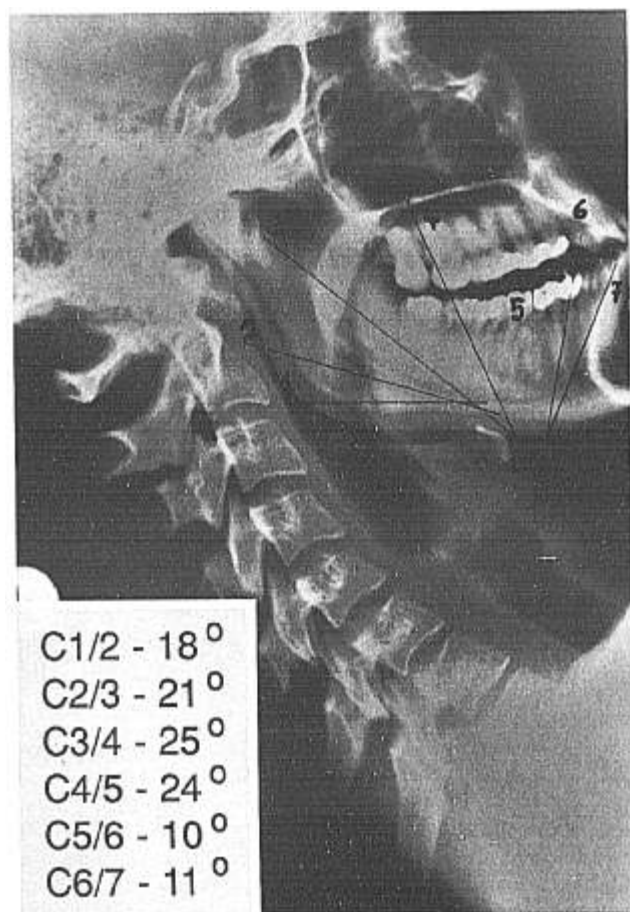


Fig 2. Example of the Penning functional diagrams of the cervical spine.

RESULTS

The healthy population consisting of 28 adults (20 women and 8 men, aged 22-47 years; mean age, 30 years) was available for examination. Thirty-one patients, who had, suffered soft tissue injury

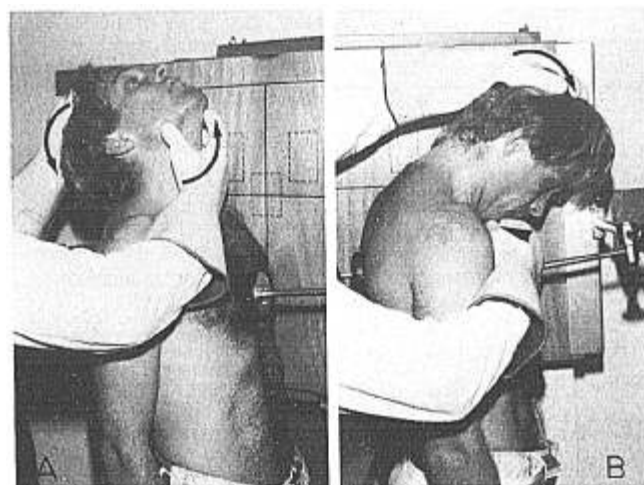


Fig 4. A, Passive inclination, flexion of the cervical spine; **B,** Passive extension.

of the cervical spine, were also examined. The groups consisted of 20 women, aged 23 to 66, and 11 men aged 21 to 54; mean age, 43.5 years. For the Penning's method, no statistically significant difference at any level was found when comparing the results of Examiner 1 with those of Examiner 2 (Table 2).

Conversely, when comparing the Buetti-Bäumli method of measurement between Examiner 1 and Examiner 3, using the same patient population and the same active and passive roentgenograms, there was a significant inter-observer difference in some of the measured values, at two levels during active and a highly significant difference at one level during passive examination. At an additional four levels there appeared to be a difference between the active and passive measurements that was not statistically validated at the 95% level of confidence (Table 3).

Based on these data and the statistical analysis, it may be stated that the Penning method of measurement is more reliable and hence more suitable than the Buetti-Bäumli method. In addition, the Penning method is less time-consuming and therefore more

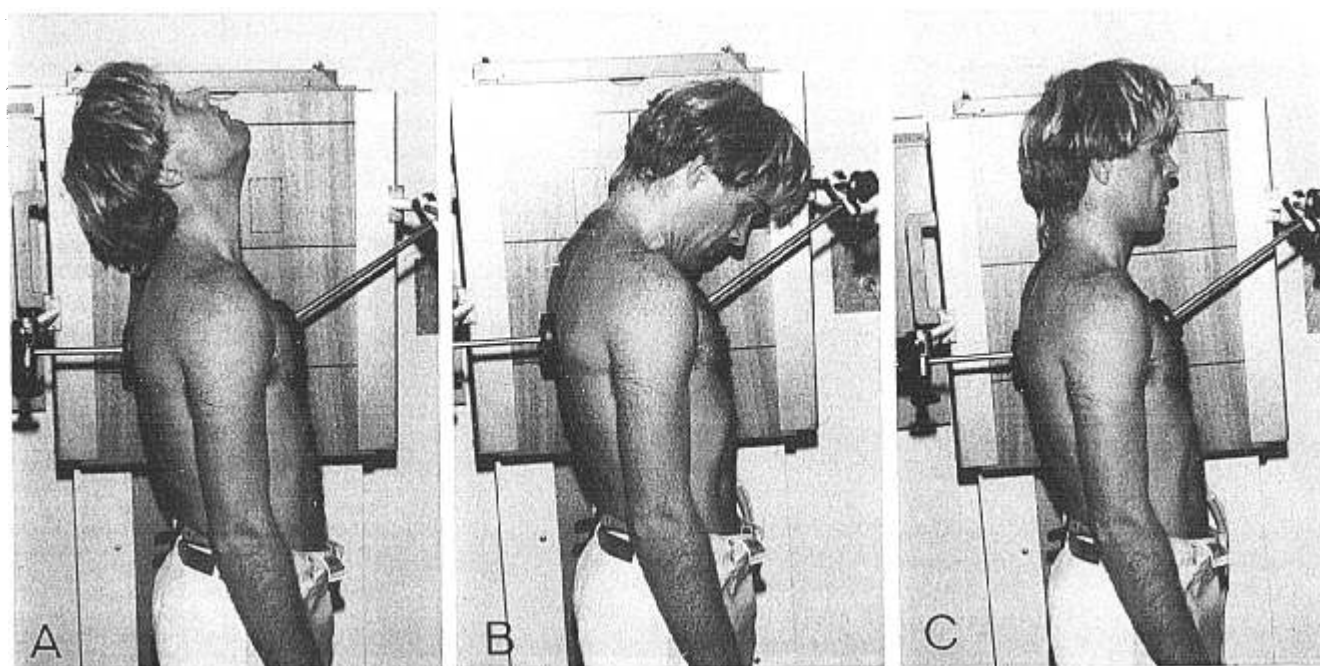


Fig 3. A, Neutral standing position, the thorax is fixed by two pellets from ventral and dorsal; **B,** Active flexion; **C,** Active extension.

Table 2. Comparison of Active and Passive Segmental Movement of the Cervical Spine Between Examiner 1 and 2 Using Penning's Method of Measurement

Segment	Probability	
	Active	Passive
C1-C2	0.24	0.33
C2-C3	0.72	0.9
C3-C4	0.91	0.88
C4-C5	0.33	0.59
C5-C6	0.33	0.11
C6-C7	0.77	0.71

n = 28.

In all segments, the difference between active and passive segmental movement is highly significant.

Table 3. Comparison of the Measured Segmental Motion and Analysis of the Values Using Student t Test Between Examiner 1 and Examiner 3 using Buetti-Bäumli's Method of Measurement

Segment	Probability	
	Active	Passive
C1/C2	0.15	0.3
C2/C3	0.006*	0.09*
C3/C4	0.005*	0.3
C4/C5	0.3	0.07
C5/C6	0.2	0.001*
C6/C7	0.03*	0.071*

* Indicates significant differences.

practical in the routine examination. Therefore, only the results from the Penning method are summarized below.

For the active examination, the mean values were as follows: C1-C2, 12° (range, 7-19), C2-C3, 10° (range, 5-15), C3-C4, 15° (range, 10-22), C4-C5, 19° (range, 14-25), C5-C6, 20° (range, 14-25), C6-C7, 19° (range, 14-27).

During the passively performed examination, the following degrees of segmental motion were determined: C1-C2, 15° (range, 9-22), C2-C3, 12° (range, 6-17), C3-C4, 17° (range, 11-26), C4-C5, 21° (range, 15-26), C5-C6, 23° (range, 17-30), C6-C7, 21° (range, 14-29).

The distribution of the active and passively measured segmental movements are shown in Figures 5 and 6 as a functional diagram of flexion/extension movement. The mean values ± 1 and ± 2 standard deviations are summarized in Tables 4 and 5.

The functional diagrams of the segmental motion during active and passive examination are compared in Figure 7. The difference between the active and passive segmental movements is highly significant at all levels of the cervical spine (Table 6).

For each of the 31 patients with soft tissue cervical spine injury, the range of motion at each level was determined. Those values were compared with the corresponding average values from the healthy population. For this study, a pathologic value was defined as one differing from the healthy population mean by one standard deviation. We found 19 hypermobile and 60 hypomobile levels in active examination (Figure 8). During the passively performed examination, 31 hypermobile and 43 hypomobile segments were measured. (Figure 9). Analyzing the significance of these data by

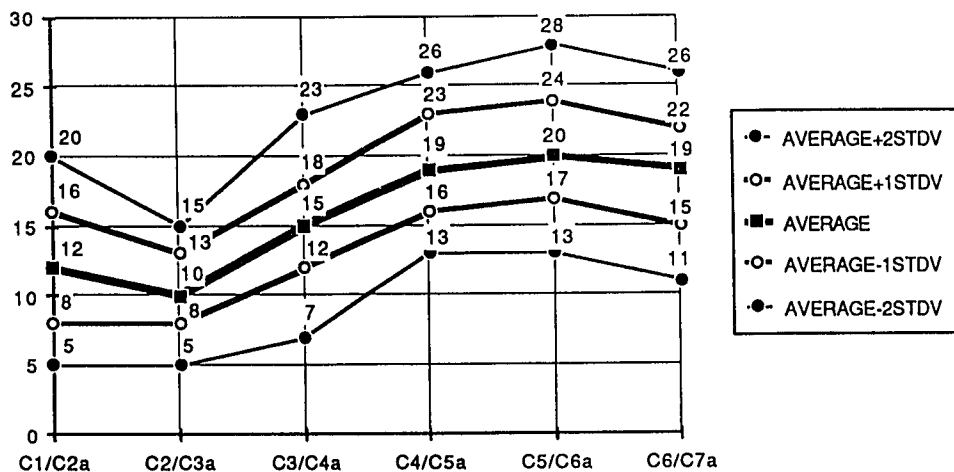


Fig 5. Functional diagram of the segmental movement of the cervical spine in sagittal plane (flexion/extension) based on the values of healthy adults (n=28).

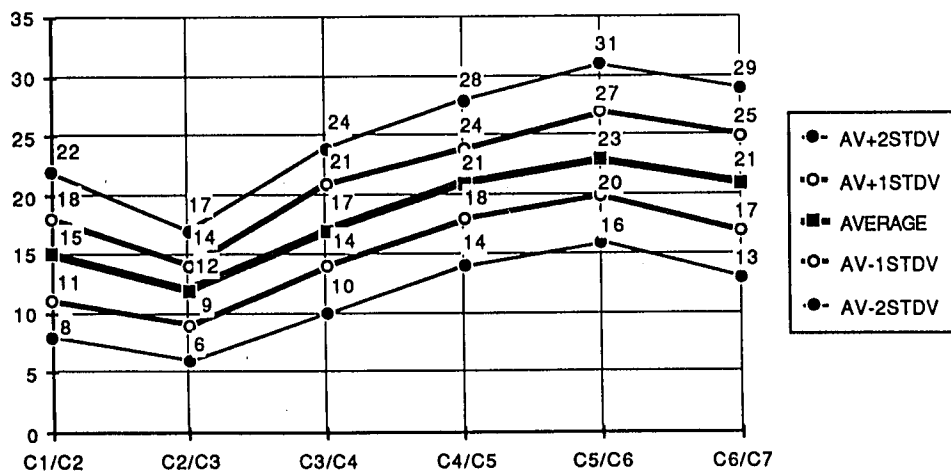


Fig 6. Functional diagram of the segmental movement of the cervical spine during passively induced movement in the sagittal plane (flexion/extension) based on the examination of healthy adults (n=28).

Table 4. Mean Value $\pm$ 1 and 2 Standard Deviation During Active Flexion/Extension by Healthy Adults*

Average Active	C1-C2	C2-C3	C3-C4	C4-C5	C5-C6	C6-C7
Average + 2 SD	20	15	23	26	28	26
Average + 1 SD	16	13	18	23	24	22
Average	12	10	15	19	20	19
Average - 1 SD	8	8	12	16	17	15
Average - 2 SD	5	5	7	13	13	11

*n = 28.

SD = standard deviation.

Table 5. Segmental Movement During Flexion and Extension of the Cervical Spine in Healthy Adults

Average Passive	C1-C2	C2-C3	C3-C4	C4-C5	C5-C6	C6-C7
Average + 2 SD	22	17	24	28	31	29
Average + 1 SD	18	14	21	24	27	25
Average	15	12	17	21	23	21
Average - 1 SD	11	9	14	18	20	17
Average - 2 SD	8	6	10	14	16	13

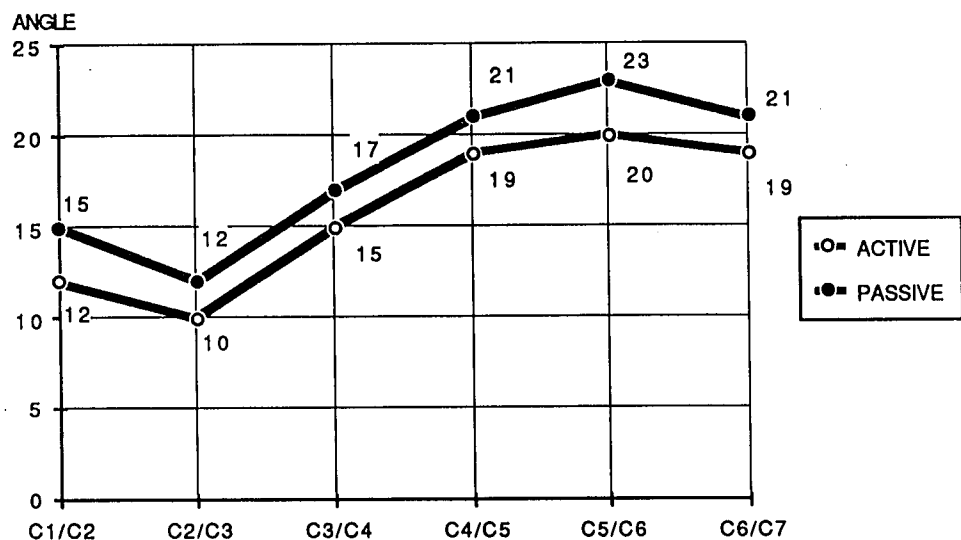
Values are mean $\pm$ 1 and 2 standard deviations (SD) (n = 28).

Fig 7. Comparison of the functional diagrams based on the active and passive examination of the flexion/extension movement of the cervical spine based on the examination in healthy adults (n=28).

using the chi square distribution, the difference in the number of hypomobile and hypermobile segments between the active and passive examination was highly significant. (Table 7). An example (Figure 10) shows the clinical significance of the results outlined

above. During passive motion, segment C3-C4 was recognized as hypermobile (Figure 10E), which would have been missed in active examination (Figure 10D).

DISCUSSION

The functional examination of the cervical spine during flexion and extension with measurement of the segmental motion in the sagittal plane is a valuable method for determining pathologic conditions such as hypo- and hypermobility. The functional roentgenogram examination, using the lateral view of the cervical spine, is widely used in Europe, employing either the method of Buetti-Bäumli or Penning.

Comparing the two widely used measuring techniques, those of Buetti-Bäumli and Penning, we found the Penning method to be more reliable and less time-consuming. In order to avoid the disadvantage of dark films during the superposition of the flexion and extension image, either the reverse films for one of the movements could be used or one of the roentgenograms should be developed with less contrast. Both techniques allow satisfactory superposition of the same vertebra.

Table 6. Comparison of the Active and Passive Segmental Movement of the Cervical Spine Using the Student t test (for Each Examiner, n = 30); in all Segments the Difference between Active and Passive Segmental Movement is Highly Significant

Segment	Probability	
	Active	Passive
C1/C2	0.0001	0.0001
C2/C3	0.0001	0.0002
C3/C4	0.0001	0.0001
C4/C5	0.0001	0.0001
C5/C6	0.0001	0.0001
C6/C7	0.0001	0.0005

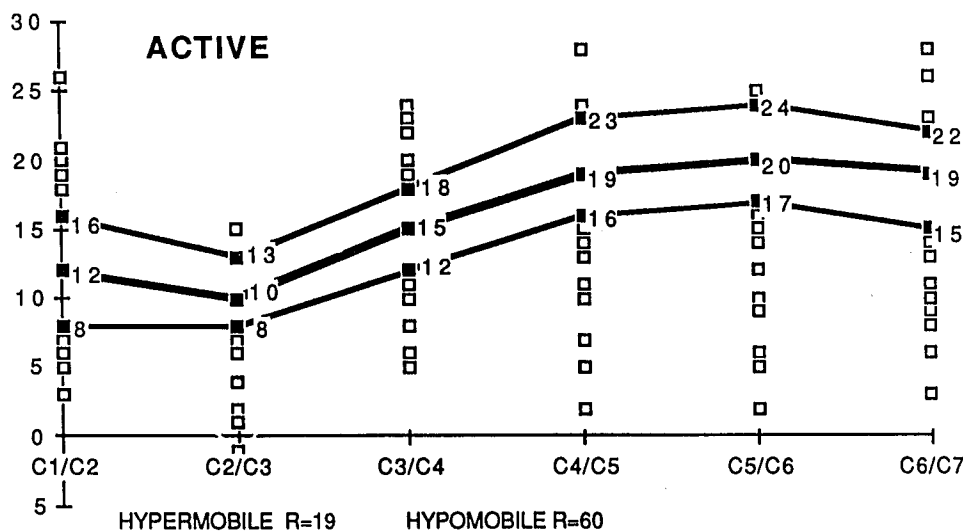


Fig 8. The functional diagram (mean value $\pm$ 1 standard deviation) and the measured hypo- and hypermobile sides in 31 patients after soft tissue injury of the cervical spine.

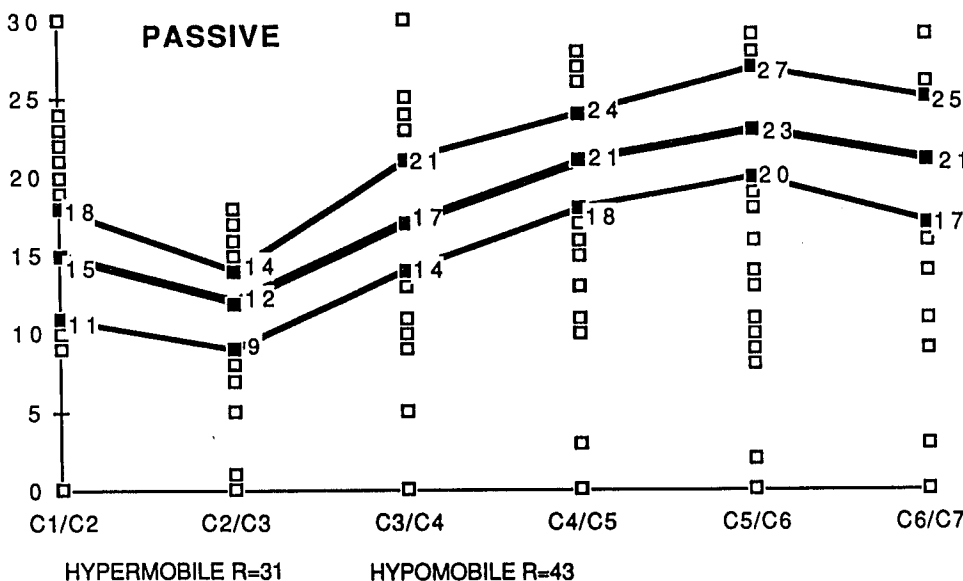


Fig 9. Functional diagram of the flexion/extension movement during passively performed examination (mean value $\pm$ 1 standard deviation) and the sides of hypo- and hypermobile segments in 31 patients after soft tissue injury of the cervical spine.

Our investigation documents the significant difference between the active and passive examination as related to the flexion/extension movement. The mean ranges of motion calculated from the passive examination were 2° to 3° greater than those found from the active examination. In addition, the results from the passive examination generally showed a smaller variance.

Table 7. Statistical Analysis of the Hypo- and Hypermobile Segments During Active and Passive Examination by Using the Chi Square Test in 31 Patients After Soft Tissue Injury

Chi-square 1SD	Hypomobile	active vs.	hypomobile	passive
	Examiner 1	0.009		
	Examiner 2	0.012		
Chi-square 1SD	Hypermobile	active vs.	hypermobile	passive
	Examiner 1	0.0302		
	Examiner 2	0.0119		

The difference as related to the segmental hypomobility and hypermobility during the active and the passive examination is highly significant.

Based on our new normal values of the active and passive movements of the cervical spine, we found a greater number of hypermobile segments among the patients when using the passive examination as compared with the active examination. Therefore, we propose the passive examination of the flexion/extension movement of the cervical spine as a more sensitive method, offering additional information for the analysis of disturbed segmental and regional movements of the cervical spine. Based on our experience with the examination on healthy volunteers and patients who commonly suffer motion-induced pain, we suggest that the passive examination be performed by the physician after the functional clinical examination of the cervical spine. The passive examination of the cervical spine is emphatically not recommended in patients in whom acute fractures or instability due to inflammatory diseases or tumors are suspected. Device-assisted examination that would allow the measurement of applied moments is not practical or advisable for healthy subjects or patients after trauma of the cervical spine.

In the future, additional information regarding the segmental movement of the vertebrae in the sagittal plane may be obtained by determining the center of rotation at each level or by determin-

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