

A CLINICAL METHOD FOR MEASURING SEGMENTAL FLEXION MOBILITY IN THE CERVICO-THORACIC SPINE AND A MODEL FOR CLASSIFICATION

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ABSTRACT. Pain and limitation of spinal mobility are symptoms frequently reported by patients. Many methods have been used to assess the total range of mobility in the different parts of the spine, but there is no method for clinical examination of segmental mobility. The aim of this study was to describe such a technique concerning of segmental flexion mobility in the cervico-thoracic spine, C7-T5, and to present a model for classification of mobility. The results of this study show that the relative flexion mobility examined, according to the Cervico-Thoracic-Ratio technique (CTR), may become a valuable complement to conventional methods of assessing mobility in the cervical spine. The normalized CTR values are less influenced by the individual factors age, body weight, height and number of years at work and the classification model presented makes functional analysis of segmental flexion mobility in the cervico- junction and upper thoracic spine more substantial.

Key words: examination, segmental mobility, classification, cervico-thoracic spine.

INTRODUCTION

Pain and limitation of spinal mobility are symptoms frequently reported by patients. Many methods have been used to assess the overall range of spinal mobility. Methods previously described are the flexicurve by Stokes et al. (13), the inclinometer by Mayer et al. (9), the kyphometer by Debrunner (2), the spondylometer by Dunham (3), and the tape measure used by Schober (12). Ålund & Larsson (15) recently described a clinical method for a three-dimensional analysis of neck motion. These methods measure the overall range of

spinal mobility, but they do not measure the segmental mobility. The methods describe the full range of mobility, either as surface curvature, altered angles, or as skin distraction.

In diagnostic radiology a method described by van Mameren et al. (8) was used to study the motion in the cervical spine, C0-C7. The method was used to determine the position of the outlines of bony structures on X-ray photographs of the cervical spine movements in the sagittal plane. Segmental range of motion and overall range of motion can be determined between C0 and C7. For the motion segments between C7 and T5 there is to our knowledge no valid method to be used in clinical practice for the physical examination of segmental mobility. This part of the spine is the functional prolongation of the cervical spine and is a difficult region to examine in clinical practice. Disturbances of motion in this part of the spine may, according to Lindgren & Leino (7), be one of the mechanisms in the thoracic outlet syndrome and in brachialgia.

The purpose of this study was to describe a technique to evaluate segmental flexion mobility in motion segments C7 to T5. The technique is intended to be used in clinical practice as a complement to other methods used for examining mobility in patients with neck-shoulder problems. Furthermore, a model for classification of mobility, based on values from healthy subjects, is presented in order to make assessments of mobility more systematic.

MATERIAL AND METHODS

Description of the technique

In this study, segmental flexion mobility was assessed indirectly by measuring skin distraction between 3 cm skin

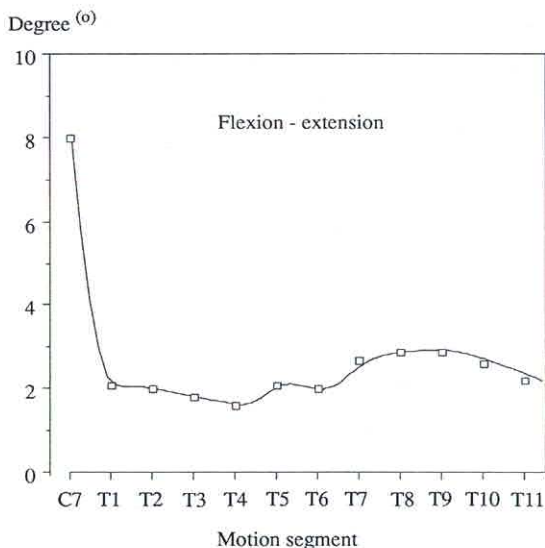


Fig. 1. Range of mobility at different spinal levels for flexion-extension. Modified from Gunnar B.J. Andersson, Biomechanics of the lumbar spine [1].

markings in the cervico-thoracic spine between C7 and T5. In a radiological evaluation of the technique it was shown that skin distraction, measured with a tape measure, approximately reproduces the segmental flexion mobility taking place between C7 and T5 (10). In the study of validity, four different regression models were used to evaluate the relationship between vertebral flexion mobility (vertebral angles) and skin distraction (X-ray markers). The results of the evaluation showed that the relationship between flexion mobility in motion segments C7–T5 and skin distraction was unique for each individual and that the polynomial regression model described the strongest relationship. For individuals the relationship expressed as r^2 ranged between

0.68 and 0.98 and for the whole group r^2 was 0.44, $P \leq 0.001$, (10).

As the height of one disc and one thoracic vertebral body is approximately 3 cm, according to Kapandji (5), the distance of 3 cm has been used as the definition of one motion segment. The measuring technique is used in the cervico-thoracic region and is referred to as the cervico-thoracic ratio (CTR). The CTR describes what is defined as *relative flexion mobility* in terms of differences in segmental mobility between C7 and T5. The CTR-technique measures both partly segmental and total skin distraction. It compares the degree of segmental flexion mobility by establishing a ratio between partly segmental and total skin distraction. The objective with describing the mobility as relative values is to reduce the influence of different individual factors such as age, weight and height. Influence of individual factors makes comparisons between individuals difficult. In the CTR-technique the individual serves as his own reference. Normalization is used in several physiological measurements.

Total spinal range of motion for flexion-extension in the cervico-thoracic spine constitutes a typical slope ranging from 8° to approximately 2° between C7 and T5 (1) (Fig. 1). Motion segment C7–T1 shows a characteristic greater degree of flexion-extension mobility compared with the gradually decreasing mobility below T1 down to T5. This characteristic distribution of mobility with the distinctive greater C7–T1 flexion mobility can be reproduced with the CTR-technique. Note that the CTR-technique only examines the mobility from neutral to maximal flexion, but not the extension as described in Fig. 1. It must be emphasized that the purpose of using the CTR-technique is not to decide the exact vertebral flexion angles for C7 to T5, but rather to describe the functional characteristics of mobility in this region, which are probably of greater clinical interest when examining a patient with neck-shoulder pain.

Examination procedure. In order to examine the CTR the first procedure is to measure what is defined as *absolute flexion mobility*. With the patient in a sitting position the examiner palpates the spinous process of C7, the reference point, then tells the patient to take an upright posture and look straight

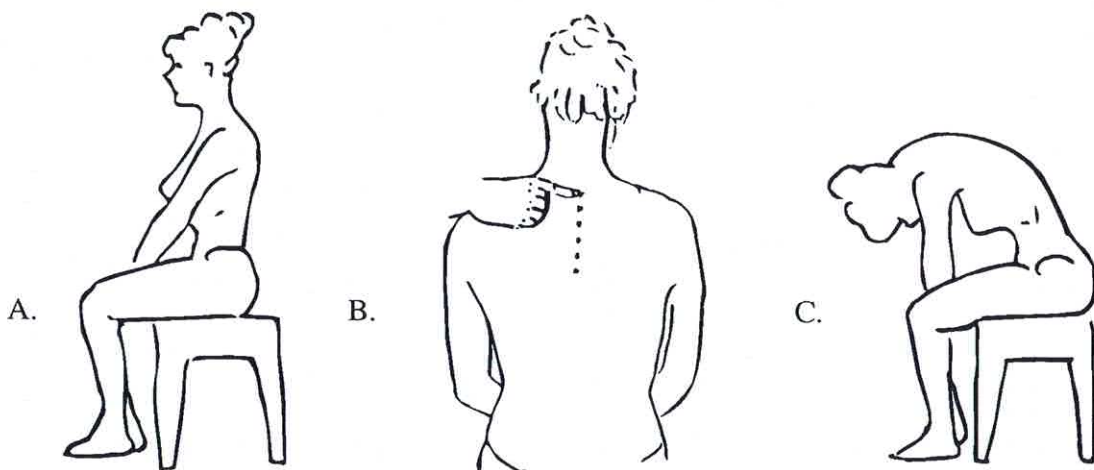


Fig. 2. Examination procedure: A, upright starting posture; B, marking of 3 cm intervals between C7 and T5; C, flexed posture during examination of absolute flexion mobility.

Table I. Calculation of the relative flexion mobility, CTR

C7-T1	$\frac{3.8}{17.4} \cdot 100 = 21.8\%$
T1-T2	$\left(\frac{7.4}{17.4} \cdot 100 = 42.5\%\right) - 21.8\% = 20.7\%$
T2-T3	$\left(\frac{10.7}{17.4} \cdot 100 = 61.5\%\right) - 42.5\% = 19.0\%$
T3-T4	$\left(\frac{14.0}{17.4} \cdot 100 = 80.5\%\right) - 61.5\% = 19.0\%$
T4-T5	$\left(\frac{17.4}{17.4} \cdot 100 = 100\%\right) - 80.5\% = 19.5\%$

head (Fig. 2 A). The most prominent part of the spinous process of C7, and with five 3 cm intervals, corresponding to one motion segment, is marked. Consequently, C7-T1=0-3 cm, T1-T2=3-6 cm, T2-T3=6-9 cm, T3-T4=9-12 cm and T4-T5=12-15 cm. An ordinary pen was used for marking (Fig. 2B).

After the marking, the patient was told to keep his chin flexed forward against the trunk and to flex his neck and trunk forward as much as possible (Fig. 2 C). The examiner used a woven tape measure to measure the absolute flexion mobility, which is shown by the alterations of skin markings between C7 and T5.

Calculation of the relative flexion mobility-CTR. After measuring the relative flexion mobility the CTR is calculated for each motion segment between C7 and T5. This part of the segmental distance is measured with C7 as reference point. The total distance is the distance between C7 and the lowest skin marking corresponding to T5.

The following example demonstrates the calculation. After a maximum flexion the absolute flexion mobility gave the following part segmental values: C7-T1=3.8 cm, C7-T2=7.4 cm, C7-T3=10.7 cm, C7-T4=14.0 cm and the value for the total distance, C7-T5=17.4 cm.

The CTR is calculated by dividing the part segmental distance for each motion segment by the total distance in cm. This calculation will show the cumulative relative flexion mobility for all five motion segments. The total cumulative relative flexion mobility is always 100% for motion segment T4-T5 (Table I).

In order to describe the degree of relative flexion mobility for each motion segment separately, the cumulative mobility from the motion segment above has to be subtracted. This subtraction is not necessary in motion segment C7-T1 (Table I).

Interpretation of the relative flexion mobility-CTR. In an upright posture the relationships between all the 3 cm part segmental distances are equal and contribute to one-fifth of the total distance between C7 and T5. Expressed as CTR, this is 20%. The value 20% thus constitutes the *starting point for equal relation* between all the five motion segments and is defined as zero in the mobility profile (MP) (Fig. 3). According to this definition, 20 must be subtracted from all CTR values

before they are inserted into the mobility profile. The horizontal axis shows the motion segments examined and the vertical axis shows the alteration from the originate zero. There are two possibilities for the CTR showing the value 20% for all motion segments after maximum forward flexion:

- No motion is taking place in the motion segments between C7 and T5 and the relations are unchanged.
- Motion is equally distributed in all five motion segments and the relations are unchanged.

From the example given (Table I), showing how to calculate the CTR, the mobility profile (Fig. 3) shows the alterations of skin markings from the originate starting point of equal relation. A value greater than 0.0% indicates that a greater degree of relative flexion mobility has taken place, compared with a motion segment showing a value less than 0.0%. In the upper motion segments, values are greater than in the lower motion segments.

The CTR-technique described is intended to be used as an aid in clinical practice to assess the distribution of flexion mobility in the cervico-thoracic junction and the upper thoracic spine. By describing the CTR values in the mobility profile the segmental distribution can be visualized, thus making assessment easier.

A model for classification of flexion mobility is also presented in this study. In order to describe such a model the influence of certain factors on flexion mobility had to be evaluated. Healthy subjects were chosen as a basis for the classification model.

Evaluation of segmental flexion mobility in healthy subjects

Study design and definition of healthy subjects. A population of 139 female laundry workers and 235 male electricians and telephone workers participated in the study. They all answered the Nordic Standardized Questionnaire about musculo-skeletal complaints, Kourinka et al. (6), and a physiotherapist clinically examined their relative flexion mobility. The following two criteria had to be fulfilled as definition of healthy subject:

- No reported neck- or shoulder pain during the past 12 months,
- relative flexion mobility in motion segment C7-T1 had to be greater than in motion segment T1-T2.

The second criterion, mobility between C7 and T1, will normally be significantly greater than mobility between T1 and T2. Andersson (1) and Norlander et al. (11) described the *C7-T1 dysfunction* as a relative flexion mobility in motion segment T1-T2 identical with or greater than that of motion segment C7-T1. This is a deviation from the normal flexion mobility in the cervico-thoracic junction.

In the female group, 26 women fulfilled both criteria for healthy subjects, 107 subjects were excluded because of neck- or shoulder pain during the past year and 6 had to be excluded because of C7-T1 dysfunction.

In the male group, 95 men fulfilled both criteria, 120 subjects were excluded because of neck- or shoulder pain during the past year and 20 individuals were excluded because of C7-T1 dysfunction.

Table II shows the age, weight, height and number of working years in the group defined as healthy female and male subjects.

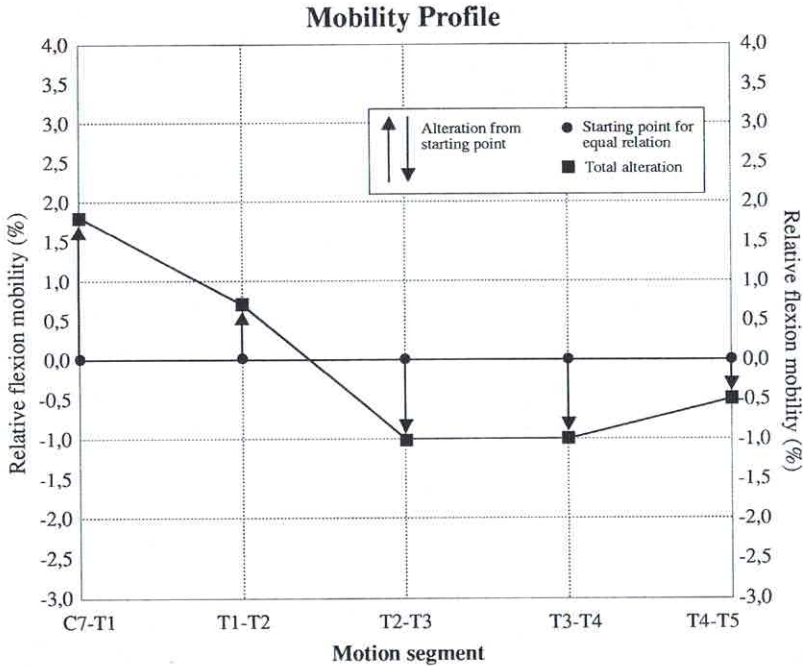


Fig. 3. Mobility profile showing relative flexion mobility from the example of calculation.

Evaluation of the influence of individual factors on segmental flexion mobility. Mobility may differ between male and female subjects and individual factors such as age, weight, height and number of working years may influence the degree of segmental flexion mobility in the cervico-thoracic spine.

To analyse the influence of individual factors, two different indices were defined: *a)* Age, Working Years Index (AWYI), defined as $(\text{age} + \text{number of working years})/2$, and *b)* Body Mass Index (BMI), defined as $(\text{weight}/\text{height}^2)$. These two indices and their influence on both absolute and relative flexion mobility were evaluated for all healthy subjects.

Model for classification of flexion mobility

Hyper-, ordinary- and hypomobility. The purpose of the classification model was to create a class defined as ordinary mobility which would comprise 50% of the variation for both absolute and relative flexion mobility in a mixed population of healthy female and male subjects. Ordinary mobility should also comprise the variation that may be caused by the influence of the two indices AWYI and BMI, for both absolute and relative flexion mobility. Three classes of flexion mobility were defined, *hyper-, ordinary, and hypomobility.*

Table II. Subject data for the two healthy study groups

	Female (n = 26)		Male (n = 95)	
	\bar{x}	SD	\bar{x}	SD
Age (years)	37.7	10.7	36.4	11.6
Weight (kg)	62.2	12.3	77.9	8.2
Height (cm)	160.8	5.5	179.3	6.6
Working years	7.8	7.5	11.4	10.0

Hypermobility was based on the values for both absolute and relative flexion mobility above the upper quartile ($> Q75$) for each motion segment between C7-T5.

Ordinary mobility was based on the values for both absolute and relative flexion mobility between the lower and upper quartile (Q25-75) for each motion segment between C7-T5.

Hypomobility was based on the values for both absolute and relative flexion mobility below the lower quartile ($< Q25$) for each motion segment between C7-T5.

Statistical analysis

The results of the study were analysed in a computer program (Quest) for statistical and epidemiological analysis. Descriptive statistics were used to describe the flexion mobility for healthy subjects and the limits in the classification model. Mean, absolute and relative flexion mobility are presented with standard deviation and 95% confidence intervals of the mean. The upper (Q75) and lower (Q25) quartiles are presented for absolute and relative flexion mobility for each motion segment.

Student's *t*-test was used for comparison between groups. Breakdowns with one-way ANOVA were used to analyse the relationship between segmental flexion mobility and the influence from AWYI and BMI. Breakdowns with one-way ANOVA were also used to study the relationship between absolute and relative flexion mobility.

RESULTS

Description of the technique

Absolute versus relative flexion mobility. The mean distribution of segmental flexion mobility and the

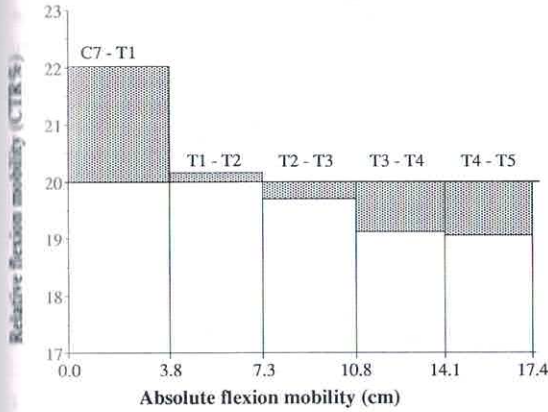


Fig. 4. Relationship between mean absolute flexion mobility (cm) and mean relative flexion mobility (CTR%) for motion segments C7 to T5 for all healthy subjects ($n = 121$).

relationship between absolute and relative flexion mobility was evaluated for motion segments between C7 and T5 in all healthy subjects (Fig. 4), (Table III). The typical distribution with a significantly larger degree of relative flexion mobility between C7 and T1 compared with motion segments below was observed when mobility was measured according to the CTR-technique (Fig. 4).

The mean relative flexion mobility ranged from 22.0% for C7-T1 to 19.1% for T4-T5. Motion segment T1-T2 increased to 20.1%, T2-T3 decreased to 19.7% and T3-T4 to 19.1%.

The mean absolute flexion mobility increased to 3.8 cm for motion segment C7-T1, to 7.3 cm for motion segments C7-T2, to 10.8 cm for motion segments C7-T3, to 14.1 cm for motion segments C7-T4 and to 17.4 cm for the total absolute flexion mobility between C7 and T5 (Fig. 4).

The analysis of relationship between absolute and relative flexion mobility shows a significant relation for motion segments C7-T1 and T1-T2, but not for motion segments T2-T3, T3-T4 and T4-T5 (Table III).

Table III. Analysis of relationship between absolute (cm) and relative (CTR%) flexion mobility for healthy female and male subjects ($n = 121$)

Motion segment	r^2	p -value
C7-T1	0.73	0.000
T1-T2	0.47	0.000
T2-T3	0.12	0.98
T3-T4	0.15	0.94
T4-T5	0.31	0.17

Evaluation of segmental flexion mobility in healthy subjects

Differences between genders in healthy subjects. The results of the study show that there are no significant differences between female and male subjects in absolute flexion mobility measured as skin distraction (in centimetres). The 95% confidence limits clearly overlap the mean value in all examined motion segments (Table IV).

Expressed as relative flexion mobility, CTR values show significant differences in distribution of flexion mobility between female and male subjects (Table IV).

Male subjects show a significantly greater degree of relative flexion mobility in motion segments C7-T1 and T1-T2 compared with female subjects. In motion segments T3-T4 and T4-T5, male subjects show a significantly smaller degree of relative flexion mobility compared with female subjects.

Influence of AWYI and BMI on flexion mobility. The breakdown with one-way ANOVA analysis of relationship between flexion mobility and AWYI shows that AWYI significantly influenced the flexion mobility in motion segment C7-T1. Both absolute and relative flexion mobility were affected. The degree of explanation between AWYI and absolute and relative flexion mobility showed that r^2 was -0.26 ($p < 0.001$) for both absolute and relative flexion mobility.

For motion segment C7-T1 AWYI influenced the absolute flexion mobility, from approximately 3.7 cm for high scores on AWYI to 3.9 cm for low scores (Table V). The corresponding influence on relative flexion mobility ranged from 21.3% for high scores to 22.2% for low scores (Table V).

The breakdown with one-way ANOVA analysis of relationship between flexion mobility in motion segments between T1 and T5 showed no significant influence of AWYI on relative flexion mobility. Absolute flexion mobility, however, showed that AWYI significantly influenced all motion segments between T1 and T5. Increasing scores in AWYI showed decreasing absolute flexion mobility ($p < 0.05$) for all motion segments.

The ANOVA analysis of the relationship between BMI and flexion mobility showed no significant influence from BMI on either absolute or relative flexion mobility in any motion segment between C7 and T5. The degree of explanation on absolute flexion mobility in motion segment C7-T1 showed an r^2 value of 0.10 ($p < 0.12$) and the corresponding

Table IV. (A) Absolute flexion mobility for healthy female and male subjects describing the cumulative flexion mobility as skin distraction for each motion segment with C7 as reference point. (B) Relative flexion mobility describing the distribution of segmental mobility

Motion segment	Female (n = 26)			Male (n = 95)		
	\bar{X}	SD	CI 95%	\bar{X}	SD	CI 95%
A. Absolute flexion mobility (cm)						
C7-T1	3.8	0.2	3.7-3.9	3.9 ns	0.3	3.8-3.9
C7-T2	7.2	0.4	7.1-7.4	7.4 ns	0.6	7.2-7.5
C7-T3	10.7	0.5	10.5-10.9	10.8 ns	0.7	10.6-10.9
C7-T4	14.1	0.6	13.9-14.4	14.0 ns	0.8	13.9-14.2
C7-T5	17.5	0.7	17.2-17.8	17.3 ns	0.8	17.2-17.5
B. Relative flexion mobility (CTR%)						
C7-T1	21.5	0.7	21.2-21.8	22.2 **	1.2	21.9-22.4
T1-T2	19.8	0.7	19.6-20.1	20.2 *	0.9	20.0-20.4
T2-T3	19.6	0.8	19.3-20.0	19.7 ns	0.9	19.5-19.9
T3-T4	19.7	1.2	19.2-20.2	19.0 **	0.9	18.8-19.2
T4-T5	19.3	0.8	19.0-19.6	19.0 *	1.0	18.8-19.2

* $p < 0.01$, ** $p < 0.05$.

degree of explanation on relative flexion mobility showed an r^2 value of 0.05 ($p < 0.41$) (Table V).

Model for classification of flexion mobility

Ordinary flexion mobility. The results show that it was possible to create a class, defined as standard mobility, which comprised 50% of the mixed population of healthy female and male subjects, and which also comprised the main influence of the variation from AWYI and BMI. The class defined as hyper- and

Table V. Relationship between flexion mobility in motion segment C7-T1 as dependent variable of age and number of working years (AWYI) for healthy female and male subjects ($n = 117$) and for body mass index (BMI) ($n = 121$)

	n	Absolute flexion mobility (cm)		Relative flexion mobility (cm)	
		\bar{X}	SD	\bar{X}	SD
AWYI					
0-10	2	3.85	0.21	22.0	1.3
10-20	47	3.93	0.26	22.2	1.0
20-30	44	3.75	0.26	21.8	1.0
30-40	21	3.71	0.29	21.8	0.8
40-50	3	3.67	0.35	21.3	1.1
BMI					
0-10	8	3.96	0.27	22.4	1.1
10-20	51	3.70	0.20	21.7	0.8
20-30	49	3.73	0.23	21.9	1.0
30-40	12	3.63	0.27	21.6	1.1
40-50	1	3.60	-	20.7	-

hypomobility, respectively, consists of 25% of the total population.

By comparing the limits for ordinary flexion mobility with the variation of AWYI and BMI, it was concluded that not in any motion segment, except for one individual value in BMI, did the extreme variation of AWYI and BMI exceed the upper or the lower quartile limits for healthy female and male subjects, respectively.

This comparison is demonstrated for motion segment C7-T1. The limits for standard mobility (Table VI) should be compared with the variation of AWYI and BMI (Table V). The comparison was also performed on the motion segments between T1 and T5. Student's t -test showed no significant difference when the factors age, weight, height and number of working years were tested between the three classes of mobility in any of the motion segments C7-T5.

The mobility profile (Fig. 5) shows the classification model with the Q25 and Q75 limits. The mean values and standard deviations for the three classes of relative flexion mobility hyper- ($> Q75$), ordinary- (Q25-75) and hypomobility ($< Q25$) is also presented.

The slope describing ordinary mobility (Fig. 5) ranges from 1.2 to 2.5% for motion segment C7-T1. Motion segment T1-T2 ranges from -0.3 to 0.7%. Motion segment T2-T3 ranges from -0.8 to 0.0%. Motion segment T3-T4 ranges from -1.4 to -0.2%. Motion segment T4-T5 ranges from -1.6 to -0.5%. This should be compared with the CTR values for standard mobility (Table VI).

Classification model

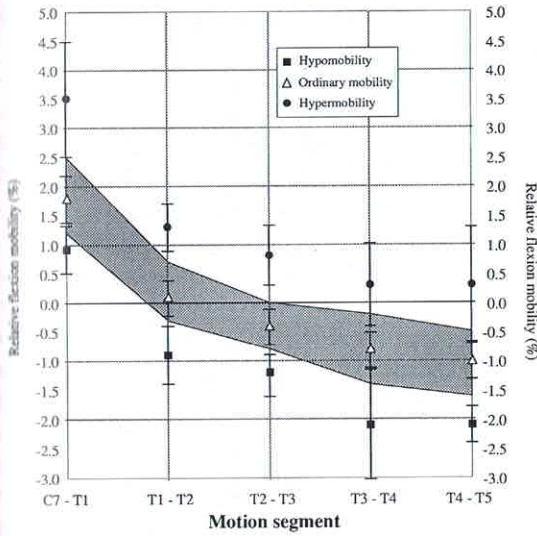


Fig. 5. Model for classification of relative flexion mobility in the cervico-thoracic spine.

Classification model

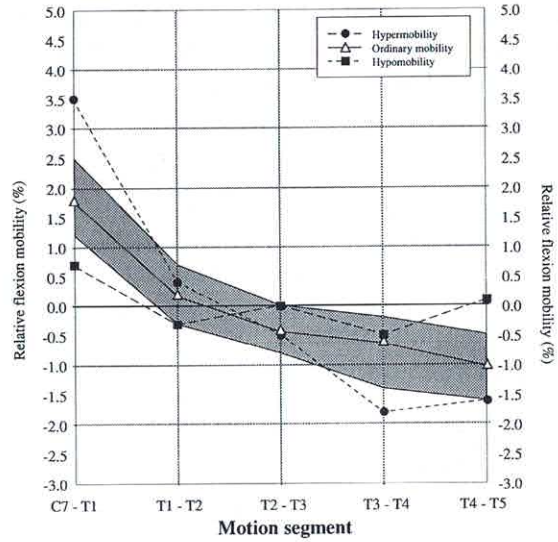


Fig. 6. Three different relative flexion mobility profiles with motion segment C7-T1 as reference for the classification.

Classification with C7-T1 as reference shows different types of relative flexion mobility. When a classification of mobility is made with motion segment C7-T1 as reference, the group classified as standard mobility in motion segment C7-T1 will constitute a roughly equal distribution of female and male subjects, 37.4% and 38.0%, respectively.

The corresponding distribution for hypomobility in motion segment C7-T1 shows 55.4% female subjects

and 35.1% male subjects. Hypermobility in motion segment C7-T1 shows 7.4% female subjects and 26.9% male subjects (Fig. 6).

The classification of flexion mobility in motion segment C7-T1 shows three different types of mobility (Fig. 6). The standard mobility in motion segment C7-T1 showed values of relative flexion mobility within the limits Q25-75 for ordinary mobility for all motion segments. The hypomobility in motion

Table VI. Limits for the classification model of flexion mobility between C7 and T5 for absolute and relative values based on the upper (Q75) and lower (Q25) quartile for all healthy female and male subjects, respectively (n = 121)

Motion segment	Hypomobility			Ordinary mobility			Hypermobility		
	Q25	\bar{X}	SD	Q25-75	\bar{X}	SD	Q75	\bar{X}	SD
<i>Absolute flexion mobility (cm)</i>									
C7-T1	< 3.6	3.5	0.1	3.6-4.0	3.8	0.1	> 4.0	4.2	0.2
C7-T2	< 6.9	6.8	0.1	6.9-7.7	7.2	0.3	> 7.7	8.0	0.3
C7-T3	< 10.2	10.0	0.2	10.2-11.2	10.6	0.3	> 11.2	11.6	0.3
C7-T4	< 13.4	13.2	0.2	13.4-14.6	14.0	0.4	> 14.6	15.0	0.4
C7-T5	< 16.7	16.4	0.2	16.7-18.0	17.4	0.4	> 18.0	18.4	0.4
<i>Relative flexion mobility (CTR%)</i>									
C7-T1	< 21.2	20.9	0.4	21.2-22.5	21.8	0.4	> 22.5	23.5	1.0
T1-T2	< 19.7	19.1	0.5	19.7-20.7	20.1	0.3	> 20.7	21.3	0.4
T2-T3	< 19.2	18.8	0.4	19.2-20.0	19.6	0.3	> 20.0	20.8	1.0
T3-T4	< 18.6	17.9	0.9	18.6-19.8	19.2	0.3	> 19.8	20.3	0.7
T4-T5	< 18.4	17.9	0.3	18.4-19.5	19.0	0.3	> 19.5	20.3	1.0

segment C7–T1 showed a value classified as hypermobility in motion segment T4–T5, while the class hypermobility in motion segment C7–T1 showed a value classified as hypomobility in motion segment T3–T4 (Fig. 6).

DISCUSSION

This study has shown that the CTR technique may become a valuable complement to conventional methods of assessing mobility in the cervical spine. It is a fact that mobility in the cervical spine is complex and dependent on adequate functions in numerous joints and muscles. Several methods used in clinical practice assess the range of motion and the motion pattern in the cervical spine according to the following definition: "Range of motion is defined as the difference between two points of physiologic extents of movement, and the motion pattern by the configuration of the path that the centre of a body describes as it moves through its range of motion" (14). The results of such measurements of cervical mobility always describe the total range of motion obtained from measurements, including several motion segments. This gives a cumulative description of mobility and may be too rough for analysing segmental dysfunction. The CTR technique analyses the flexion mobility in a single motion segment and may therefore become a valuable complement to conventional analysis of mobility in the future.

Mobility in the cervical spine described from a strictly anatomical point of view is mobility between C0–C7. From a functional point of view this description is unsatisfactory, since mobility in the cervical spine also is dependent on the mobility in the cervico-thoracic junction and the upper thoracic spine, C7–T5. As the CTR technique is focused on the function of segmental flexion mobility in this part of the spine it is most likely an important complement.

The examination procedure as described in the CTR technique shows the active flexion mobility between C7 and T5. According to Gajdoski & Bohannon (4) the best repeatability is obtained if mobility is tested actively. In a study of intra- and intertester repeatability it was shown that the CTR technique showed high intratester repeatability, the coefficient of variation (VC) was found to be 4.4%. The intertester repeatability was found to be fair, VC 7.7%, Norlander et al. (10).

By calculating the CTR the examiner can assess the

relative flexion mobility as normalized values. The normalized CTR values were shown to be less influenced by the individual factors age, body weight, height and number of working years, compared with absolute flexion mobility, except for motion segment C7–T1.

When the limits, as described in the classification model, were used, the class defined as ordinary mobility comprised the total influence from the two indices AWYI and BMI for all motion segments, including C7–T1 (Tables V–VI). In conclusion, the range of relative flexion mobility, as described in the ordinary mobility class, comprises the total variation from the individual factors studied. This makes functional assessments using the classification model more substantial.

The mobility profile (MP) as described (Fig. 3) is a pedagogic aid with which to visualise the distribution of segmental flexion mobility in a fashion which resembles both range of motion and motion pattern in one segment. This gives the examiner a clear picture of the patient's relative flexion mobility, and in combination with the classification model (Fig. 5) it is also possible to assess the characteristics of, for example, flexion mobility in the cervico-thoracic junction.

The results of the study also demonstrate that absolute and relative flexion mobility measure different aspects of mobility. Absolute flexion mobility only considers an increasing skin distraction between two points. The analysis of absolute flexion mobility from the C7–T1 motion segment includes mobility from the reference point C7 down to T1. The next absolute value includes flexion mobility from two motion segments, C7 down to T2. If the measuring is continued further down, mobility from the next segment below adds to the previous segments above in a cumulative description of mobility (Fig. 4). This conventional way of measuring mobility, including several motion segments, fails to reveal the differences in distribution between segments.

The CTR technique instead focuses on the distribution of mobility between motion segments separately (Fig. 4). This is achieved by the fact that calculation of the CTR includes a subtraction of the mobility from the motion segments above (Table I). This calculation results in fundamental differences between absolute and relative flexion mobility and is most likely the reason why the degree of relationship between absolute and relative values declines when several motion

segments are included for absolute flexion mobility (Table III).

The results of the study show that there were no significant differences between healthy female and male subjects when mobility was measured as absolute flexion mobility. The relative flexion mobility, however, showed significant differences between genders (Table IV). These differences can be described as functional differences in distribution and are clearly demonstrated in the classification model, which was based on values from both female and male subjects (Fig. 6). The classification model shows that both female and male subjects were found in all three classes. The standard mobility class showed an equal distribution of female and male subjects, while females were more numerous in the hypomobility class and male subjects in the hypermobility class, when relative flexion mobility was classified with motion segment C7-T1 as reference.

From a clinical point of view it is obviously more important to determine the functional characteristics of flexion mobility than the differences between genders. Therefore a classification model based on flexion mobility values from both female and male subjects is more favourable.

The female and male study groups represented two rather extreme habitual working postures. The male subjects work frequently with the neck in extension looking upwards, while female subjects work frequently with the neck in flexion looking downwards, both groups work frequently with arms elevated. As the proportions were equal between genders in the standard mobility class, there has to be some factor explaining the differences in proportions of hyper- and hypomobility between genders. It is evident that the results of this study cannot be used to evaluate the influence of working postures on flexion mobility. However, it cannot be ruled out that habitual working postures may affect flexion mobility in some way, which could explain the differing distribution between flexion mobility classes. This has to be further evaluated.

The results of the classification model show three quite different distributions of relative flexion mobility in the cervico-thoracic junction (Fig. 6). The hypomobile function in C7-T1 lacks the characteristic greater degree of mobility and shows a fairly uniform distribution of mobility in each segment. The converse is the hypermobile function in C7-T1,

showing extreme mobility in motion segment C7-T1. Both hypo- and hypermobile C7-T1 classes, however, show an opposite functional compensation in adjacent motion segments according to the classification model described (Fig. 6).

These differences in functional characteristics of the cervico-thoracic junction have been shown to be of clinical significance. In a case-control study "Mobility in the cervico thoracic junction—an indicative factor in neck-shoulder pain" Norlander et al. (11), clearly demonstrated that both female and male subjects classified as hypomobile in C7-T1 showed a significantly increased risk of having suffered from neck-shoulder pain during the preceding 12 months, compared with the classes standard and hypermobility, respectively.

CONCLUSIONS

- Relative flexion mobility measured according to the CTR technique may become a valuable complement to conventional methods of assessing mobility in the cervical spine.
- The normalized CTR values are less influenced by the individual factors: age, body weight, height and number of working years.
- The classification model makes the functional analysis of mobility in the cervico-thoracic junction and upper thoracic spine more substantial.

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