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A Clinical Method for Measuring the Distribution of Segmental Flexion Mobility in the Cervico-Thoracic Spine

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ABSTRACT

The aim of this study was to evaluate the validity and the repeatability of a new technique to assess segmental flexion mobility in the cervico-thoracic spine between segments C7 and T5. The new technique is referred to as the Cervico-Thoracic-Ratio (the CTR-technique). The radiological evaluation of skin distraction measurements showed that validity was high for the CTR-technique. A high correlation between vertebral flexion mobility and skin distraction was recognized individually and for the whole group. The evaluation of repeatability was found to be high for intratester and fair for intertester repeatability. The CTR-technique may become a valuable complement to other methods for assessing segmental flexion mobility in patients suffering from neck-shoulder pain in clinical practice.

INTRODUCTION

A new technique has been described to measure the segmental flexion mobility in the cervico-thoracic junction and the upper thoracic spine (7). The measuring technique is referred to as the Cervico-Thoracic-Ratio (the CTR-technique). The CTR-technique describes what is defined as *relative flexion mobility* (CTR%). Relative flexion mobility is a calculated ratio based on absolute values of skin distraction between C7 - T5. *Absolute flexion mobility* is defined as the measured alteration in cm between 3 cm interdistant skin markings marked from C7 down to T5 and measured with a tape measure after a maximal forward flexion of the trunk and neck from an upright posture. The distance of 3 cm marked, in the upright posture, has been used as the definition of one motion segment, as the height of one disc and one thoracic vertebral body is approximately 3 cm, according to (5).

The validity of the CTR-technique is dependent on an individual and strong *relationship between vertebral flexion mobility and skin distraction* in the motion segments between C7 and T5, since the method is meant to be used for individual assessment of flexion mobility. Several attempts have been made to establish the relationship between spinal mobility and different methods for clinical examination. According to (2) and (9) clinical examinations and radiographic measurements showed high validity for measurement of lumbar curvature during stance and trunk forward flexion.

According to (1) and (10) different clinical examinations showed poor validity compared with measurements from radiographic pictures. In conclusion, validity differs for different instruments and methods. The CTR-technique has to be evaluated in order to become a reliable method for clinical examination of the segmental flexion mobility.

Repeatability is defined as the capability to repeat a measurement. Many clinical methods for examination of spinal mobility are known to show low repeatability. Different factors affect the repeatability, for example if the mobility is tested passively or actively, or how long the time interval is between repeated measurements. According to (3) the best repeatability is obtained if the mobility is tested actively and with as short time interval as possible between measurements, the classic *"test-retest design"*. In the CTR-technique mobility is tested actively. Repeatability is also known to be higher when it is performed by one tester, *intratester repeatability*, compared with measurements done by two testers, *intertester repeatability*. In order to get acceptance of the CTR- technique the repeatability also has to be evaluated. The aim of this study is to evaluate the validity and the repeatability of the CTR- technique as a method to be used in clinical practice for assessment of the segmental flexion mobility between C7 and T5.

MATERIALS AND METHODS

Radiological evaluation of validity

The validity of the CTR-technique is dependent on an individual and strong relationship between vertebral flexion mobility and skin distraction in motion segments between C7 and T5. In order to study the *individual* relationship six different vertebral angles C7 to T5 were evaluated against six corresponding skinmarkings for each subject. The analysis of relationship was also evaluated for the whole group of 42 different vertebral angles versus 42 corresponding skinmarkings. Seven male subjects with pain in the neck-shoulder region, mean age 40.3, (SD16.0) years participated in the evaluation of validity. The evaluation was only done on male subjects, since previous studies did not show any significant differences between female and male subjects with reference to the degree of skin distraction, during forward flexion measured according to the CTR-technique(7).

Procedure. Six small metal markings were glued onto the skin with 3 cm intervals, according to the marking procedure described in the CTR-technique. The markers were glued with the subject in an upright sitting posture and the upper marking put over the most prominent part of the spinous process of C7. Lateral radiographs were used to obtain overlay measurements of the alteration of vertebral angles and of skin marker (Fig. 1). The first radiograph was taken with the subject in an upright sitting posture and the second in a maximal flexed sitting posture. Since the spinous processes could not be demonstrated in the thoracic region without tomography, the angle between the vertebral endplates were used as the independent variable. An aluminium wedge was used in order to equalize the contrast differences and to visualize the metal markers on the skin. The angles between the endplates and the distances between the markers were measured on the films with the patient in upright position and in maximal forward flexion. The T6-vertebra was used as a reference vertebra, the cumulative angles of C7 down to T5 were measured with a gauge. The diagonal alteration of metal skin markers M1 - M6 were measured with a pair of compasses and a ruler (Fig. 1). The measurements were done only once.

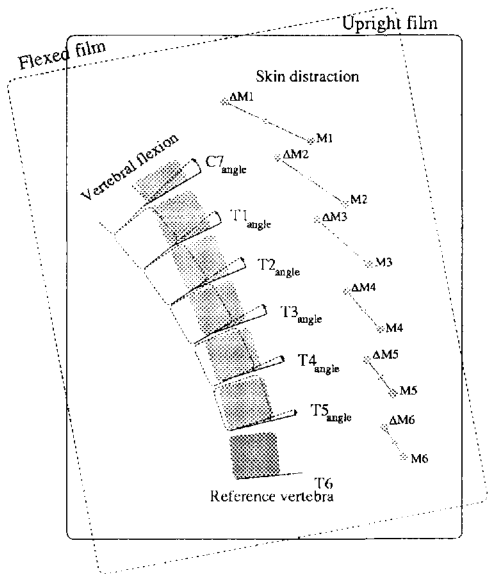

Figure 1 Lateral radiographs were used to obtain overlay measurements of the cumulative vertebral angles (C7 - T5) and the diagonal alterations of the metal markings (M1 - M6).

Statistical analysis. The determination of the relationship between skin distraction and vertebral flexion mobility was done by deciding the highest regression coefficient for five different regression models. Both the relationship for the individual and the whole group was evaluated for each model. A computer program (Quest) calculated the equation for linear (Y=A+B*X), exponential (Y=A*exp (B*X)), power (Y=A*X^B), logarithmic (Y=A+B*ln (X)) and polynomial models ($Y=A-B_1*X + B_2* X^2$). Vertebral angles were used as the independent variable, and skinmarkers as the dependent variable. Breakdowns with one-way anova were also used to describe the mean values of the dependent variable skinmarkers as a function of the independent variable vertebral angles.

Evaluation of repeatability

The evaluation of repeatability was done for intra- and intertester repeatability. Tests were done by two investigators, two trials each. The evaluation was done with a test-retest design on 26 male subjects, mean age 41.2, (SD 9.3) years.

Procedure . On arrival the subject was instructed to sit in a chair. The first investigator put the markings on the subject according to the examination procedure described in the CTR-technique, and the subject was asked to flex forward as much as possible. The investigator measured and noted all the five alterations. After that the markings were erased. The same procedure was repeated by the second investigator. Finally a second trial was repeated by both investigators, altogether four trials.

Statistical analysis. In the evaluation of repeatability a sign-test was used to reveal systematic errors. Random errors were evaluated by calculating the measuring precision and the relative measuring error. Both absolute and relative flexion mobility was evaluated. The precision was calculated as the pooled standard deviations of the differences between trials or investigators, divided by the extracted square root of two. The relative measuring error, the coefficient of variation (CV) was calculated as the standard deviation divided by the mean, times 100. Breakdown with one way anova was used to analyse the degree of conformity between intra- and intertester repeatability expressed as R square and p-values.

RESULTS

Evaluation of validity

The results of the analysis of the relationship between vertebral flexion mobility and skin distraction show that the validity of the CTR-technique was individually very high. (Table 1). The degree of relationship varied between different regression models, which implies an individual variation of spinal flexion mobility. The polynomial model showed the highest degree of individual relationship in five subjects, the logarithmic model in two subjects and the power model and the linear model showed equally high values as the polynomial model in one subject each. The different r^2 values ranged between 0.68-0.98, which is a very high degree of explanation and all seven subjects showed a statistically significant relationship in at least one of the models (Table 1).

Table 1 Results of individual relationships between dependent variable skin distraction and independent variable vertebral angles.

Regression models										
Sub-	Linear		Exponential		Power		Logarithmic		Polynomial	
jects	r^2	p-value	r^2	p-value	r^2	p-value	r^2	p-value	r^2	p-value
1	0.58	0.08	0.61	0.07	0.68	0.04	0.61	0.07	0.68	0.18
2	0.96	0.002	0.89	0.006	0.95	0.002	0.95	0.002	0.96	0.008
3	0.91	0.004	0.83	0.13	0.88	0.007	0.93	0.003	0.92	0.023
4	0.93	0.003	0.87	0.008	0.93	0.003	0.96	0.002	0.94	0.012
5	0.68	0.04	0.56	0.09	0.44	0.14	0.56	0.09	0.82	0.07
6	0.11	0.52	0.07	0.61	0.00	1.0	0.01	0.81	0.91	0.03
7	0.91	0.004	0.97	0.001	0.81	0.04	0.70	0.08	0.98	0.003

For the whole group the polynomial regression model showed the strongest relationship between vertebral flexion mobility and skin distraction, r^2= 0.44 and p<0.001, (n=42) (Fig. 2). The linear model showed r^2= 0.39, (p<0.001), (n=42), the exponential model r^2= 0.27 (p<0.001), (n=42), the power model r^2= 0.19 (p<0.005), (n=42) and the logarithmic model showed r^2 = 0.28 (p<0.001), (n=42). The mean cumulative vertebral angle for C7 was 18° and the alteration of the ΔM1 skinmarker was 5.3 cm. The cumulative flexion mobility for T1 and ΔM2 was 13° versus 3.8 cm. T2 and ΔM3 was 8.1° versus 3.0 cm. T3 and ΔM4 was 5.9° versus 2.5 cm. T4 and ΔM5 was 5.1° versus 2.1 cm. T5 and ΔM6 was 4.6° versus 1.8 cm (Fig. 2).

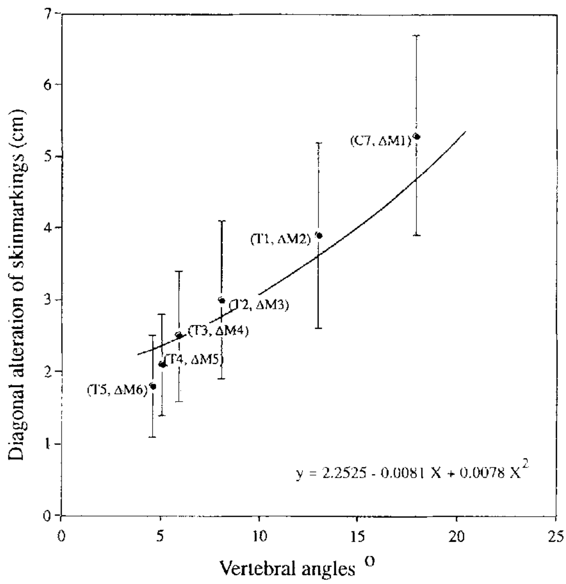

Figure 2 Regression model describing the highest relationship between vertebral angles (C7 - T5) and alteration of skin markings (ΔM1 - ΔM6) ($r = 0.66$, $p<0.001$) ($n = 42$). Mean values (± SD) for studied variables.

The breakdowns with one-way anova analysis showed a relationship similar to the polynomial model (Table 2) between vertebral angles and skin distraction, r^2 was 0.41 and p-value 0.001. Increasing vertebral angles showed increasing skin distraction.

Table 2 The breakdown with one-way anova analysis showed a similar relationship between vertebral angles and alterations of skinmarkings, $r^2 = 0.413$ and $p< 0.001$ ($n = 42$).

Vertebral angles ( )°	Skinmarkings (cm) $\bar{X}$	SD	Min		Max	Number of joints
0 - 6	2.335	0.916	0.600	-	4.200	17
6 - 12	2.883	1.389	1.300	-	5.800	12
12 - 18	3.622	1.645	1.300	-	5.800	9
18 - 24	5.300	0.781	4.400	-	5.800	3
24 - 30	6.700	—	6.700	-	6.700	1
Total	3.083	1.546	0.600	-	6.700	42

Evaluation of repeatability

Absolute flexion mobility. The results of the evaluation showed that repeatability was high for absolute flexion mobility, for both intra- and intertester repeatability, which was important, as the values of relative flexion mobility exclusively depended on the values of absolute flexion mobility. The absolute flexion mobility was measured in cm according to the description of the CTR-technique from motion segment C7 down to T5. The *intratester* repeatability showed no systematic error between the first and second trial either for tester 1 or tester 2, when absolute flexion mobility was evaluated for all motion segments. The sign test did not show any significant differences between trials for the two testers (Table 3, 1* and 2*).The *intertester* repeatability, comparing tester 1 with tester 2 showed a small, but significant systematic measuring error between testers in both trials and in all five motion segments, (Table 3, 3* and 4*). Tester 2 systematically measured a 2-3 mm shorter absolute flexion mobility for all motion segments. The random errors expressed as measuring precision (mm) and as relative measuring error CV showed that repeatability was high for both intra- and intertester repeatability (Table 3, 1* and 4*). In general the precision is higher the shorter the distance measured , while the CV is greater. The CV for *intratester* repeatability ranged from 2.1-4.8% for tester 1 and from 1.9 - 4.4% for tester 2 for the different motion segments (Table 3, 1* and 2*). The CV for *intertester* repeatability ranged from 2.4- 5.7% for trial 1 and from 1.8-4.1% for trial 2 for the different motion segments (Table 3, 3* and 4*). The breakdown with one way anova analysis describing the relationship between repeated trials for absolute flexion mobility showed a very high degree of conformity, r^2 values ranged 0.995 - 0.998 and p-values was $p<0.001$, for both intra- and intertester repeatability.

Table 3 Results from evaluation of repeatability of absolute flexion mobility (n = 26), 1* and 2* = intratester, 3* and 4* = intertester repeatability.

Motion segment	Trial	Tester	Absolute flexion mobility (cm) X	SD	Random errors	Measuring precision (mm)	Measuring error (CV%)	Systematic errors	Sign test
C7 - T1	1	1	3.8	0.2	1*	1.8	4.8	1*	ns
	2	2	3.6	0.2	2*	1.6	4.4	2*	ns
	3	1	3.8	0.2	3*	2.1	5.7	3*	0.01
	4	2	3.6	0.2	4*	1.5	4.1	4*	0.01
C7 - T2	1	1	7.3	0.3	1*	2.7	3.6	1*	ns
	2	2	7.1	0.4	2*	2.4	3.4	2*	ns
	3	1	7.3	0.3	3*	3.1	4.3	3*	ns
	4	2	7.1	0.3	4*	2.5	3.5	4*	0.01
C7 - T3	1	1	10.6	0.4	1*	2.7	2.5	1*	ns
	2	2	10.5	0.5	2*	2.5	2.4	2*	ns
	3	1	10.6	0.4	3*	4.2	4.0	3*	ns
	4	2	10.4	0.5	4*	2.8	2.6	4*	0.01
C7 - T4	1	1	14.0	0.5	1*	3.1	2.3	1*	ns
	2	2	13.8	0.6	2*	3.0	2.2	2*	ns
	3	1	14.0	0.5	3*	3.6	2.6	3*	0.05
	4	2	13.7	0.5	4*	3.1	2.2	4*	ns
C7 - T5	1	1	17.4	0.5	1*	3.6	2.1	1*	ns
	2	2	17.1	0.6	2*	3.3	1.9	2*	ns
	3	1	17.3	0.5	3*	4.1	2.4	3*	0.02
	4	2	17.1	0.6	4*	3.0	1.8	4*	ns
Total									
1* Intratester repeatability tester 1			10.60	4.8		2.8	3.1		ns
2* Intratester repeatability tester 2			10.40	4.8		2.6	2.9		ns
3* Intertester repeatability trial 1			10.51	4.8		3.4	3.8		0.01
4* Intertester repeatability trial 2			10.49	4.8		2.6	2.8		0.01

Relative flexion mobility. Relative flexion mobility expressed as CTR% is based on two values of absolute flexion mobility. This makes relative values afflicted with a somewhat greater measuring error. The *intratester* repeatability showed no systematic errors between the first and second trial either for tester 1 or tester 2 when relative flexion mobility was evaluated for all motion segments. The sign test did not show any significant differences between trials for the two testers (Table 4, 1* and 2*). The *intertester* repeatability, comparing tester 1 with tester 2, showed a significant systematic measuring error between testers in both trials for motion segment C7-T1 and T4 - T5 (Table 4, 3* and 4*). The systematic measuring error in absolute flexion mobility between testers resulted in a calculated CTR value which in average is 0.7% lower for motion segment C7-T1 and 0.4% higher for motion segment T4 - T5 for tester 2 compared with tester 1. The random errors expressed as measuring precision (%) and as relative measuring error CV showed that repeatability was high for intratester repeatability and fair for intertester repeatability (Table 4, 1* and 4*). In general the precision is higher in motion segments C7-T1 and T4 - T5 and so is also the CV compared with motion segments in between. The CV for *intratester* repeatability ranged from 2.9-3.9% for tester 1 and from 2.9 - 4.4% for tester 2 for the different motion segments (Table 4, 1* and 2*) The CV for *intertester* repeatability ranged from 5.4- 7.7% for trial 1 and from 3.2-7.7% for trial 2 for the different motion segments (Table 4, 3* and 4*).

Table 4 Results from evaluation of repeatability of relative flexion mobility (n = 26), 1* and 2* = intratester, 3* and 4* = intertester repeatability.

Motion segment	Trial	Tester	Relative flexion mobility (CTR%) X̄	SD	Random errors Measuring precision (%)		Measuring error (CV%)	Systematic errors Sign test	
C7 - T1	1	1	21.8	1.2	1*	0.9	3.9	1*	ns
	2	2	21.2	1.0	2*	0.8	3.5	2*	ns
	3	1	22.1	0.9	3*	1.3	6.3	3*	0.02
	4	2	21.3	1.1	4*	0.7	3.2	4*	0.01
T1 - T2	1	1	20.0	0.9	1*	0.6	3.1	1*	ns
	2	2	20.4	1.3	2*	0.9	4.4	2*	ns
	3	1	20.0	0.8	3*	1.1	5.4	3*	ns
	4	2	20.0	1.4	4*	1.3	6.4	4*	ns
T2 - T3	1	1	19.3	1.0	1*	0.6	2.9	1*	ns
	2	2	19.8	1.3	2*	0.8	3.8	2*	ns
	3	1	19.6	1.0	3*	1.1	6.0	3*	ns
	4	2	19.6	1.7	4*	1.5	7.7	4*	ns
T3 - T4	1	1	19.7	1.6	1*	0.7	3.7	1*	ns
	2	2	19.4	1.5	2*	0.7	3.7	2*	ns
	3	1	19.5	1.5	3*	1.5	7.7	3*	ns
	4	2	19.3	1.3	4*	1.3	6.8	4*	ns
T4 - T5	1	1	19.3	1.7	1*	0.7	3.7	1*	ns
	2	2	19.3	1.0	2*	0.6	2.9	2*	ns
	3	1	18.8	1.4	3*	1.4	7.0	3*	ns
	4	2	19.6	1.0	4*	1.0	5.3	4*	0.02
Total									
1* Intratester repeatability tester 1			20.0	1.5		0.7	3.5		ns
2* Intratester repeatability tester 2			20.0	1.3		0.8	3.7		ns
3* Intertester repeatability trial 1			20.0	1.2		1.3	6.5		0.01
4* Intertester repeatability trial 2			20.0	1.3		1.2	5.9		0.01

The breakdown with one way anova analysis, describing the relationship between repeated trials for relative flexion mobility, showed a very high degree of conformity. Intratester repeatability showed a $r^2 = 0.79$ ($p<0.001$) for tester 1 and a $r^2 = 0.68$ ($p<0.001$) for tester 2. Intertester repeatability showed a $r^2 = 0.38$ ($p<0.001$) for trial 1 and a $r^2 = 0.58$ ($p< 0.001$) for trial 2. Not in any motion segment did the variation of repeatability significantly exceed the limits for what is defined as ordinary mobility in the classification model, described by (7), (Fig. 3).

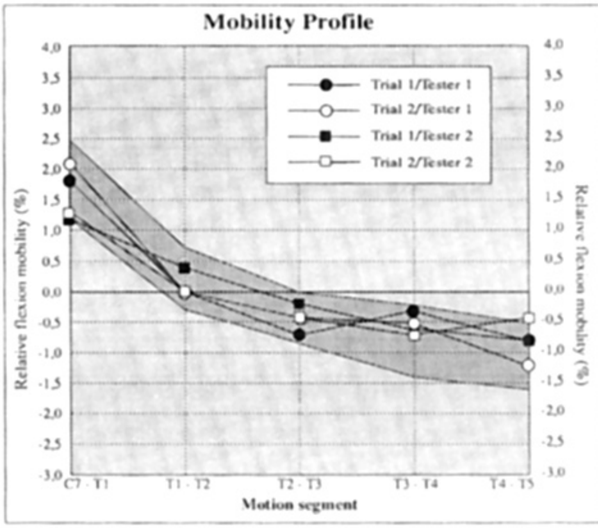

Figure 3 The results of the intra- and intertester repeatability evaluation shown in the mobility profile. The variation between trials and testers is kept within the limits for ordinary mobility.

DISCUSSION

The results of this study have shown that the distribution of segmental flexion mobility in the cervico-dorsal region can be examined with the CTR-technique. The validity of skin distraction measurements in the cervico-dorsal spine was found to be individually very high. In this study it was necessary to use conventional X-ray technique to evaluate the relationship between skin distraction and vertebral motion. It was also necessary to choose the vertebral endplates to study the alteration of vertebral angles since the spinous processes could not be clearly identified in this difficult region. Great efforts were made to optimize the technique. The number of subjects was limited to seven, since the relationship between individual vertebral flexion mobility and skin distraction was found to be convincingly high for our application. The aim with the CTR-technique was assessment of joint flexion mobility, from a clinical point of view. The aim was not to decide the exact vertebral angle in degrees. Further more the method has shown an important clinical application as an instrument to identify dysfunction in the cervico-thoracic junction correlating to neck-shoulder pain (8). The evaluation of validity was done on patients suffering from neck-shoulder pain and the evaluation of repeatability was done on healthy subjects. This was not a problem, since clinical trial has shown that the CTR-method can distinguish between different flexion mobility in individuals with and without increased risk for neck-shoulder pain (8).

The intratester repeatability demonstrated high repeatability and was not impaired by any systematic measuring error.The intertester repeatability demonstrated fair repeatability for both absolute and relative flexion mobility. The measuring procedure was impaired by a small but systematically measuring error for both absolute and relative flexion mobility, values between testers showed slightly different characteristics. It was most likely that the marking procedure of the 3 cm interdistant penmarkings contributed to the systematic measuring error. However, for absolute flexion mobility, the relative measuring error must be considered small, only in one trial and for one motion segment did the CV exceed 5% (Table 3). As tester 2 systematically measured a 2-3 mm shorter absolute flexion mobility for all motion segments, the calculation of the CTR resulted in a value which on an average was 0.7% lower for motion segment C7-T1 and 0.4% higher for motion segment T4 - T5 for tester 2 compared with tester 1. This increased CV to 7.7% as the highest for relative flexion mobility. This variation in intertester repeatability for relative flexion mobility was, however, not greater than it was comprised within the limits for what was defined as ordinary mobility in the classification model described by (7). Consequently the systematic measuring error for intertester repeatability was less than what was defined as ordinary variation between individuals. As the CTR was a ratio between two absolute flexion mobility values, it was quite obvious that the relative value was impaired by a somewhat greater measuring error compared with absolute values. If the precision in absolute values could be improved by approximately 1 mm in each motion segment, the CV would decline and not exceed the 5% limit for relative calculations. This could most likely be achieved by using an instrument with fixed 3 cm interdistances for marking instead of an ordinary tape measure.

Only a few studies have used the coefficient of variation (CV) of their data to describe repeatability and to our knowledge nobody has studied measurements in the thoracic spine according to the CTR-technique. The present study was therefore difficult to compare with other studies. However, some studies must be commented on. Gill et al (4) found that the intratester variation was 1.5% for the low back measurements using the modified Schober technique, with the subject examined in a fully flexed sitting posture. Meritt et al (6) found a 6.6% intratester variation with the modified Schober technique, examined in a fully flexed standing posture. Thus, also other skin distraction methods have shown values of coefficient of variation of the same magnitude.

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