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MOBILITY IN THE CERVICO-THORACIC MOTION SEGMENT: AN INDICATIVE FACTOR OF MUSCULO-SKELETAL NECK-SHOULDER PAIN

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ABSTRACT. The aim of the study was first to evaluate whether mobility in the cervico-thoracic motion segment is an indicative factor of musculo-skeletal neck-shoulder pain and secondly to compare differences in individual factors between cases and controls for female and male subjects. One-hundred-and-forty-two male electricians and 139 female laundry workers participated in a cross-sectional study. An examination of the Cervico-Thoracic Ratio and a classification of mobility at level C7–T1 was done. All subjects answered a questionnaire about musculo-skeletal complaints.

The analysis of relationship between relative flexion mobility in motion segments C7–T5 and neck-shoulder pain showed significant relationships between mobility in specific motion segments and neck-shoulder pain. The overall fit of the multiple regression analysis explained 10% of the variation in neck index (NI) for subjects classified as hypomobile at level C7–T1 and 18% for subjects classified as having an inverse C7–T1 function. Both female and male subjects classified as hypomobile at level C7–T1 showed elevated odds ratios of 2.7 and 2.2, respectively, to have had more than 7 days of neck pain during the previous 12 months, compared to subjects classified as having ordinary mobility at level C7–T1.

The factor age showed that young subjects with hypo- or hypermobility at level C7–T1 showed elevated odds ratios for neck pain compared to subjects with ordinary mobility in the same age group. In old subjects hypermobility at level C7–T1 was protective compared to subjects with ordinary mobility in the same age group. The factor number of working years showed significant difference between cases and controls among female subjects in the ordinary and hypermobile classes. The factor height showed no significant differences between female or male cases and controls; it did show significant correlation to C7–T1 mobility among female subjects, but not among male subjects. The factors exercise and smoking showed significant differences between cases and controls among female subjects in the ordinary mobility class. The conclusion was that relative flexion mobility is a factor related to the development of neck-shoulder pain rather than the cause of pain.

Key words: cervico-thoracic motion segment, indicative factor, mobility, neck-shoulder pain.

INTRODUCTION

Work-related injuries in the neck-shoulder region are a growing problem in industrial countries (15). Altogether there are some 20 more or less commonly adopted symptom diagnoses used to describe such work-related neck-shoulder pain (13). According to Silverstein (14) and Hagberg & Wengman (3) female industrial workers run a six times greater risk of getting "tension neck syndrome" than male industrial workers do. Different work tasks where repetitive arm elevations are frequent cause a four times greater risk for Thoracic Outlet Syndrome (TOS) (3).

Mobility in the cervico-thoracic motion segment and the upper thoracic spine is not very often considered as a factor in work-related neck-shoulder pain, though symptoms of stiffness and restricted motion are frequently reported by patients. However, in Lindgren & Leino's study (7), it is suggested that disturbances of motion in the cervico-thoracic junction can cause brachialgia, as well as being one of the mechanisms in the thoracic outlet syndrome.

In clinical practice it has been difficult to measure and assess mobility in the cervico-thoracic motion segment. Norlander et al. (9) recently described a method, the Cervico-Thoracic Ratio (CTR), which makes measuring and assessment of segmental mobility between C7 and T5 possible. The CTR technique also describes a model for classification of mobility in three different classes, ordinary mobility, hyper- and hypomobility, respectively.

The aim of the study was to evaluate whether differences in segmental flexion mobility are indicative of musculo-skeletal neck-shoulder pain and to compare differences in individual factors between cases and controls for both female and male subjects.

METHODS AND MATERIAL

Measuring procedure

The CTR technique has been described in order to measure the segmental flexion mobility in the cervico-thoracic motion segment and the upper thoracic spine, which can be looked upon as the functional prolongation of the cervical spine. The CTR technique describes what is defined as relative flexion mobility (CTR%), which is a calculated ratio based on absolute values of skin distraction between C7 and T5. Marking the distance of 30 mm, in an 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 30 mm according to Kapandji (5).

Absolute flexion mobility is defined as the measured changes in millimetres (mm) between the 30 mm interdistant skin markings, marked from the vertex of the spinous process of 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 CTR technique has been described in a previous study by Norlander et al. (9), as well as the validity and repeatability of the CTR technique (10).

Classification model for mobility

The classification model for relative flexion mobility, described by Norlander et al. (9), was created so that the class ordinary mobility comprised 50% of the variation for relative flexion mobility in motion segments C7 to T5 in a mixed population of healthy female and male subjects. It also comprised the normal variation of relative flexion mobility caused by the individual factors age, height and body weight (9). The hyper- and hypomobility classes each comprised 25% of the mixed healthy population. In motion segment C7–T1 the limits for relative flexion mobility for the ordinary mobility class ranges from 21.2 to 22.5% of the total relative flexion mobility between C7 and T5. The hypermobility class C7–T1 was defined as relative flexion mobility greater than 22.5% and the hypomobility class relative flexion mobility less than 21.2%. The ordinary CTR% limits for motion segments C7–T5 are shown in the shaded area (Figs. 1–3). The horizontal line at CTR 20% constitutes the starting point for equal relation between all five motion segments C7–T5 (Figs. 1–3).

Mobility between C7 and T1 normally shows a significantly greater degree of mobility compared to mobility between T1 and T2 (1). Inverse C7–T1 function is defined as greater or equal relative flexion mobility in motion segment T1–T2, compared with motion segment C7–T1. Such a deviation from the normal sequence of relative flexion mobility is defined as inverse C7–T1 function.

Cases and controls

In order to evaluate whether differences in segmental flexion mobility in the cervico-thoracic motion segment were indicative of musculo-skeletal neck-shoulder pain, 142 male electricians and 139 female laundry workers participated in a cross-sectional study. An examination of the CTR and a classification of mobility in the cervico-thoracic motion segment was done. All the subjects answered the standardized Nordic questionnaire about musculo-skeletal complaints

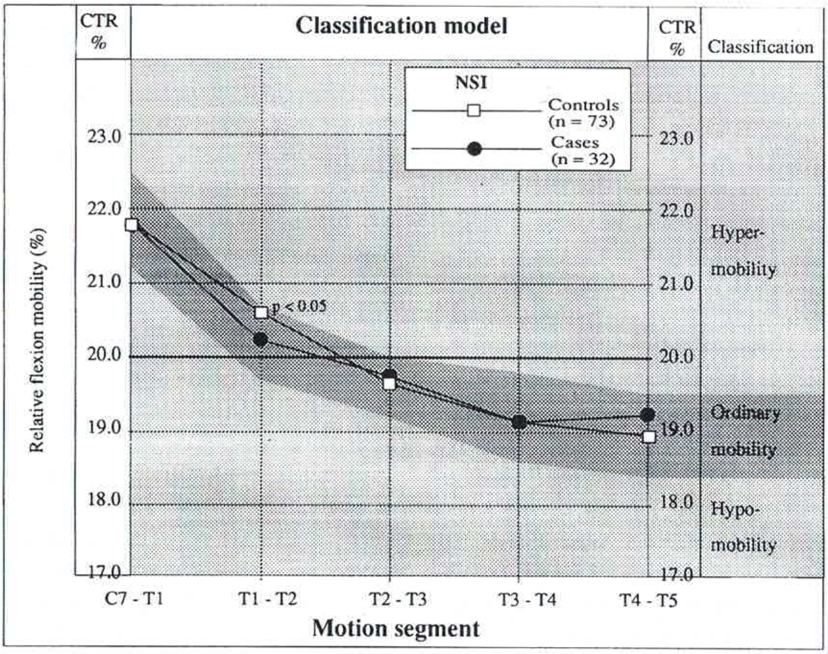

Fig. 1. Classification model describing the synchronicity of mobility for motion segments C7 to T5, according to the CTR technique by Norlander, showing the CTR% mobility profile for the class ordinary mobility at level C7–T1.

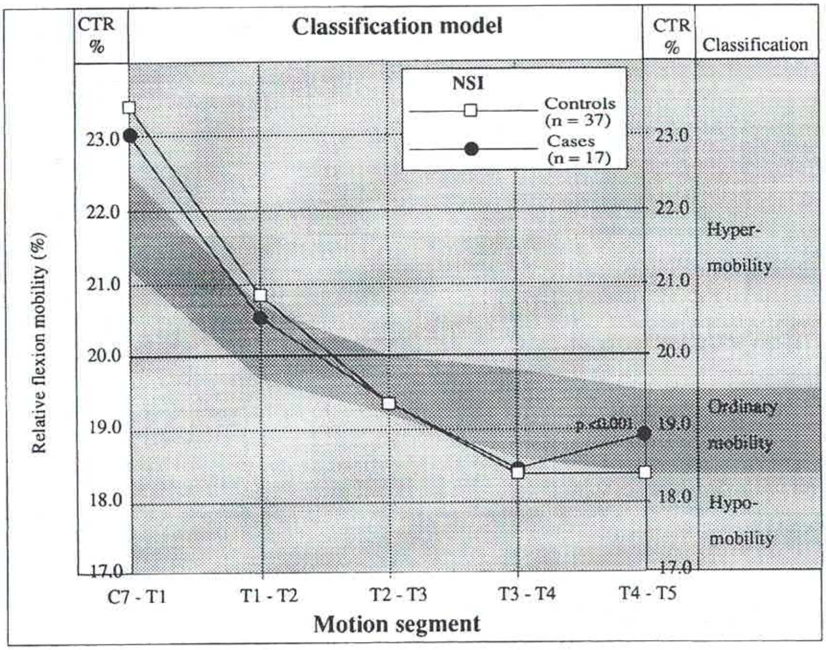

Fig. 2. Classification model describing the synchronicity of mobility for motion segments C7 to T5, according to the CTR technique by Norlander, showing the CTR% mobility profile for the class hypermobility at level C7–T1.

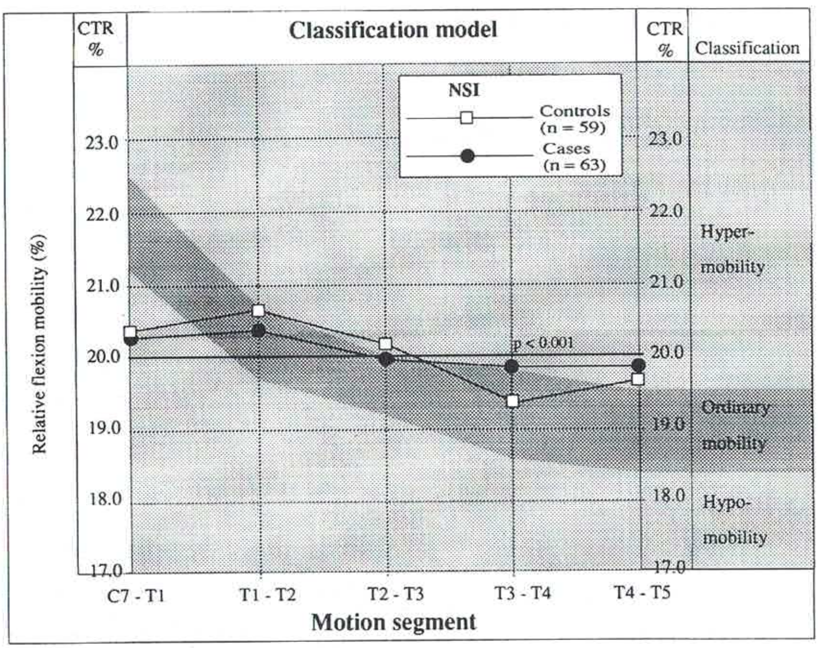

Fig. 3. Classification model describing the synchronicity of mobility for motion segments C7 to T5, according to the CTR technique by Norlander, showing the CTR% mobility profile for the class hypomobility at level C7–T1.

(6). The examination was carried out without the examiner's knowledge of the subjects answers to the questionnaire, and the subjects were instructed not to mention whether they had complaints or not.

Complementary questions about individual factors; age, number of working years, weight, height, exercise (walking, jogging or racket sports) and smoking habits were added to the questionnaire. The questions for exercise and smoking were: "Do you exercise?", "Do you smoke?" The answers were separated into two categories; no or yes. Individual factors are presented separated for female and male cases and controls and also for each mobility class (Tables I and II). In the different evaluations of age, five male subjects were not included because answers regarding age were missing. With reference to neck index (NI), two of the missing subjects were in the class with ordinary mobility, one was defined as case and one as control. In the class with hypermobility two missing subjects were defined as cases and one as control.

Three different indices for neck-shoulder pain were evaluated, namely neck index (NI), shoulder index (SI) and neck-shoulder index (NI + SI)/2 (NSI) versus the different classes of mobility. The questions for NI and SI, respectively, were: "For how long altogether have you during the last 12 months had complaints from the neck and/or the shoulders?" The answers for NI and SI, respectively, were separated into five different categories; 1 = 0 days, 2 = 1–7 days, 3 = 8–30 days, 4 => 30 days (but not daily), 5 = daily. All three indices NI, SI and NSI ranged from 1 to 5. Subjects having more than 7 days of complaints in NI and/or SI, respectively, were defined as cases. Subjects having 7 days or less of complaints in NI and/or SI, respectively, were defined as controls. In NSI, cases had to have had more than 7 days of complaints from both NI and SI. The concept of cases and controls as used in this study always refers to the definition above. The distribution of mobility was compared as CTR values between cases and controls within mobility classes. The distribution of cases and controls between mobility classes was compared as odds ratio. The total number of female cases with reference from NI was 66 and controls 73. For male subjects the total number of cases was 46 and controls 96. A question about the experience of neck pain during the previous 7 days was also asked, where cases were defined as answering yes and controls no.

Statistical analysis

A computer program (Quest) for statistical and epidemiological analysis was used for evaluation. Comparisons of differences in individual factors and in the distribution of segmental flexion mobility (CTR%) between cases and controls were evaluated for each motion segment C7 to T5 within a mobility class and tested with an unpaired *t*-test. A multiple linear regression analysis with forced entry was performed in order to evaluate which of the five motion segments entered into the regression model that showed the strongest relationship to the dependent variables NI, SI and NSI, respectively. In order to describe the total influence of relative flexion mobility between C7 and T5 on NI, SI and NSI, respectively, an overall fit of the regression model expressed as R square was presented for each mobility class and also for subjects classified as having an inverse C7–T1 function. The relative differences in occurrence of cases and controls between mobility classes were evaluated as odds ratio (8) for the index NI. The odds ratio is considered to be an estimate of the relative risk and was chosen in order not to underestimate the differences in occurrence of neck pain in the different mobility classes, since prevalence rates may underestimate the differences when prevalence is high. Age standardization was applied by stratifying in the following age groups: 18–29, 30–45 and 46–65 years and is reported as standardized relative risk. The relationship between the individual factor height and mobility at level C7–T1 was evaluated with Pearson's correlation coefficient for female and male subjects, respectively.

Table I. *Comparison of individual factors for different classes of mobility and between cases and controls in the female subject group*

Female subjects with reference from neck index

	Hypomobility				Ordinary mobility				Hypermobility			
	Control ($n = 28$)		Case ($n = 42$)		Control ($n = 38$)		Case ($n = 21$)		Control ($n = 7$)		Case ($n = 3$)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Age (years)	39	12.4	40.5	10.1	35.1	11.9	43.7**	9.7	33.0	10.6	42.0(*)	1.7
Number of working years	10.0	7.5	10.0	6.8	5.6	6.7	10.9**	7.3	5.7	4.5	15.2*	4.5
Weight (kg)	63.8	10.9	66.4	11.5	59.8	10.3	64.6	11.9	59.5	5.0	60.3	4.5
Height (cm)	163.6	6.4	164.4	6.8	162.6	5.7	161.0	5.0	161.0	8.0	160.7	4.9
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Exercise %	25	75	26	74	24	76	0	100*	29	71	0	100
Smoking %	64	36	51	49	47	53	81	19*	71	29	100	0

$p < 0.1$*, $p < 0.05$*, $p < 0.01$**.

Table II. *Comparison of individual factors for different classes of mobility and between cases and controls in the male subject group*

Male subjects with reference from neck index

	Hypomobility				Ordinary mobility				Hypermobility			
	Control ($n = 31$)		Case ($n = 21$)		Control ($n = 34$)		Case ($n = 10$)		Control ($n = 29$)		Case ($n = 12$)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Age (years)	30.6	10.3	35.3	13.0	35.1	11.9	38.0	14.8	38.2	13.4	34.5	14.5
Number of working years	10.3	8.9	16.2$^{(*)}$	14.2	16.6	12.2	20.6	15.9	17.7	13.8	17.0	13.7
Weight (kg)	77.8	7.6	85.4	16.6	78.3	8.3	79.2	8.8	78.3	9.9	80.3	5.6
Height (cm)	177.7	5.8	177.8	8.3	179.6	5.7	180.2	4.2	180.2	7.4	178.0	5.6
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Exercise %	20	80	29	71	22	78	25	75	41	59	38	62
Smoking %	68	32	81	19	78	22	75	25	55	45	62	38

$p < 0.1$*.

RESULTS

Synchronicity of mobility in motion segments C7 to T5 in relationship to neck-shoulder pain

In order to study the synchronicity of mobility, i.e. how mobility was distributed between motion segments C7 and T5, subjects were classified in three classes with reference to the degree of relative flexion mobility at level C7–T1. Among the female subjects 43% ($n = 59$) were classified as having ordinary mobility at level C7-T1, 7% ($n = 10$) as having hypermobility and 50% ($n = 70$) as having hypomobility. Among the male subjects 32% ($n = 46$) were classified as having ordinary mobility at level C7-T1, 31% ($n = 44$) as having hypermobility and 37% ($n = 52$) as having hypomobility. There was a significant difference between female and male subjects in the hypermobile class ($p \leq 0.01$). A total of 38 female subjects showed inverse C7–T1 function and 92% of them were found in the hypomobile class. A total of 44 male subjects showed inverse C7–T1 function and 82% of them were found in the hypomobile class.

Looking at synchronicity of relative flexion mobility in motion segments C7 to T5 the *t*-test showed differences in synchronicity between classes as well as significant differences between cases and controls for NSI (Table III, Figs. 1–3). In the ordinary class there was a significant difference between cases (20.2%) and controls (20.6%) in relative flexion mobility at level T1–T2 (Table III, Fig. 1). The multiple regression analysis showed that level T1–T2 was the strongest determinant of SI of all five motion segments entered into the regression model. The standard regression coefficient for level T1–T2 was −0.30 ($p < 0.01$) after removing not significant variables from the regression model.

In the hypermobile class there was a significant difference in flexion mobility between cases (18.9%) and controls (18.3%) at level T4–T5 (Table III, Fig. 2) and there was a sharp deviation in mobility for cases compared to the even hypermobile slope for subjects classified as controls. The multiple regression analysis showed that level T4–T5 was the strongest determinant of NI, SI and NSI, respectively, of all the five motion segments entered into the regression model, but not significant.

In the hypomobile class (Table III, Fig. 3) there was a sharp deviation from an even slope in motion segment C7–T1 for both cases and controls and there was also a significant difference in flexion mobility at level T3–T4 between cases (19.8%) and controls (19.3%). The multiple regression analysis showed that levels T3–T4 and T4–T5 were the strongest determinants of NI of all five of the motion segments entered into the regression model. The standard regression coefficient for level T3–T4 was 0.23 ($p < 0.01$) and for level T4–T5 0.18 ($p < 0.05$) after removing not significant variables from the regression model. The synchronicity at levels C7–T1 and T1–T2 showed an inverse C7–T1 function in the hypomobile class (Fig. 3).

For subjects classified as having an inverse C7–T1 function irrespective of mobility class, the multiple regression analysis showed that level T1–T2 was the strongest determinant of NI of all five of the motion segments entered into the regression model. The standard regression coefficient for level T1–T2 was −0.38 ($p < 0.01$) after removing not significant variables from the regression model. The interpretation of this result is that a lack of mobility at levels C7–T1 and T1–T2 resulted in increasing values in NI. A greater CTR value at level T1–T2 resulted in a lower value in NI.

In the regression model (Table IV) the overall fit of relationship between relative flexion mobility in motion segments C7 to T5 versus NI, SI and NSI, respectively, showed significant relationships between mobility and neck-shoulder pain. In the hypomobile class there was a significant relationship for NI and NSI. R square was 0.10 ($p < 0.05$) and 0.11 ($p < 0.05$), respective (Table IV). The ordinary mobility class showed a significant relationship versus SI. R square was 0.09 ($p < 0.05$) (Table IV). There were no significant relationships between relative flexion mobility and the different pain indices in the hypermobility class (Table IV).

In the regression model the overall fit showed the strongest relationships between flexion mobility and the different pain indices among subjects classified as having an inverse C7-T1 function irrespective of mobility class. R square was 0.18 ($p < 0.01$) for NI, 0.22 ($p < 0.003$) for SI and 0.22 ($p < 0.002$) for NSI, respectively.

Individual factors and mobility at level C7-T1

The individual factors age, number of working years, weight, height, exercise and smoking habits were evaluated for the three classes of C7–T1 mobility, and the differences between cases and controls were compared in both the male and female groups (Tables I–II). Female cases classified as having ordinary mobility at level C7–T1 were significantly older, had worked for more years, and there were significantly more subjects who exercised and fewer smokers than female controls (Table I). In the hypermobile female class the factor number of working years showed a significant difference between cases and controls (Table I). In the male subject group no significant differences were found, only a tendency for the factor number of working years in the hypomobile class (Table II). The factor height showed no significant differences between female or male cases and controls in any class of mobility (Tables I–II). Height showed significant correlation versus C7–T1 mobility among female subjects ($r = -0.17, p < 0.05$), but not among male subjects ($r = 0.10$). In order to study the influence of age on NI, a comparison between subjects aged 18–29 years was done versus subjects aged 20–45 and 46–65 years. The results show elevated odds ratios for older age groups versus younger (Fig. 4a)

Comparisons between different mobility classes with reference from mobility at level C7–T1 and neck pain

Neck pain during the previous 12 months. Comparisons between different classes of C7–T1 mobility and the

Table III. *Relative flexion mobility (CTR%) for motion segments C7 to T5 for all three classes of mobility classified with reference from level C7–T1 and a comparison of mobility between cases and controls with reference from neck–shoulder index.*

	Ordinary mobility level C7–T1				Hypermobility level C7–T1				Hypomobility level C7–T1			
	Controls ($n = 73$)		Cases ($n = 32$)		Controls ($n = 37$)		Cases ($n = 17$)		Controls ($n = 59$)		Cases ($n = 63$)	
Motion segment	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
C7–T1	21.8	0.4	21.8	0.4	23.4	1.1	23.0	0.9	20.3	0.6	20.2	0.6
T1–T2	20.6	0.9	20.2*	0.8	20.8	0.9	20.5	0.6	20.6	1.1	20.3	0.8
T2–T3	19.6	0.6	19.7	0.8	19.3	1.3	19.3	0.3	20.1	1.2	19.9	0.7
T3–T4	19.1	0.9	19.1	0.6	18.3	1.1	18.4	0.5	19.3	1.0	19.8***	0.7
T4–T5	18.9	0.8	19.2	0.9	18.3	0.7	18.9***	0.5	19.6	1.0	19.8	0.6

$p < 0.05$*, $p < 0.01$**, $p < 0.001$***.

Table IV. *Multiple regression analysis (r^2) describing the relationship between the dependent variables NI, SI and NSI, respectively, in different classes of mobility versus five independent variable motion segments C7 to T5*

Mobility C7–T1	NI r^2	SI r^2	NSI r^2	Subjects (n)
Hypomobility	0.10*	0.09$^{(*)}$	0.11*	122
Ordinary mobility	0.05	0.09*	0.08	105
Hypermobility	0.10	0.11	0.11	54
Total	0.06**	0.07**	0.08***	281

$p < 0.1^{(*)}$, $p < 0.05$*, $p < 0.01$**, $p < 0.001$***.

number of controls and cases, respectively, in NI, showed elevated odds ratios for both female and male subjects. This was valid in the class with hypomobility at level C7–T1 versus the class with ordinary mobility at level C7–T1 (Table V). The class with hypermobility at level C7–T1 versus ordinary mobility showed elevated odds ratios for male subjects and lowered odds ratios for female subjects (Table V).

Stratified in age groups 18–29, 30–45 and 46–65 years a comparison was done with subjects classified according to the CTR classification model. The evaluation showed an opposite result to only the influence of age on NI (Fig. 4B–C). Elevated odds ratios were found in the young age group 18–29 years for both hypo- and hypermobility versus ordinary mobility at level C7–T1 (Fig. 4B–C, Table VI). In summary, the hypomobility class showed elevated odds ratios in all age groups versus ordinary mobility, while the hypermobile class showed elevated odds ratios in young subjects and lowered odds ratios in old subjects compared with corresponding age groups with ordinary mobility at level C7–T1 (Table VI). The age standardized rate ratios (SRR) showed elevated ratios for both the class with hypo- and hypermobility at level C7–T1 versus ordinary mobility at level C7–T1, SRR 2,7 and SRR 1.4, respectively (Table VI).

Neck pain during the last 7 days. The experience of neck pain during the previous 7 days for all male and female subjects in the age group 18–45 years was 7% in the class with ordinary mobility, 15% in the class with hypomobility and 6% in the class with hypermobility at level C7–T1. In the age group 46–65 years it was 10% in the class with ordinary mobility, 9% in the class with hypomobility and 0% in the class with hypermobility at level C7–T1. In the group 18–45 years the odds ratio was 2.1 (CI 95% 0.9–5.1) for the hypomobile class experiencing neck pain compared to the class with ordinary mobility and in the class with hypermobility versus ordinary mobility the odds ratio was 0.6 (CI 95% 0.2–2.6). In the group 46–65 years the odds ratio was 0.9 (CI 95% 0.3–2.8) for the class with hypomobility versus ordinary mobility, and 0.0 for the class with hypermobility, as no cases were found in this age group among subjects with hypermobility.

DISCUSSION

This study included 142 male electricians and 139 female laundry workers. It was shown that differences from normal in relative flexion mobility in the cervico-thoracic motion segment was an indicative factor of musculo-skeletal neck pain. Both male and female subjects classified as hypomobile in all age groups in the cervico-thoracic motion segment had a greater "risk" of reporting neck pain than subjects classified as ordinary mobility in the cervico-thoracic motion segment (Table V). Hypermobility in the cervico-thoracic motion segment showed elevated odds ratios among male subjects and lowered ratios among female subjects compared to subjects classified as ordinary mobility at level C7–T1 (Table V).

The evaluation of synchronicity of flexion mobility in motion segments C7–T5 showed differences in the distribution of segmental mobility between classes as well as between cases and controls (Table III, Figs. 1–3). In the class with ordinary mobility at level C7–T1 the multiple regression analysis showed that decreased mobility in motion segment T1–T2 was a significant determinant of SI. The overall fit expressed as R square (Table IV) showed that relative flexion mobility explained 9% of the variation in SI. No differences were found in any other motion segments between C7 and T5, which may indicate that levels above C7–T1 may be involved, giving rise to shoulder pain, or that factors such as tendinitis or impingement of the rotator cuff without relation to segmental mobility are involved. In the hypermobile class there was a significant difference between cases and controls at level T4–T5 (Table III, Fig. 2). The multiple regression analysis showed that motion segment T4–T5 was the strongest determinant of NI, SI and NSI, respectively. The overall fit expressed as R square (Table IV) showed that relative flexion mobility explained 11% of the variation in SI and NSI, but this was not

Table V. *Odds ratio comparing male and female subjects in the hyper- and hypomobility classes versus the ordinary mobility class with reference from NI*

	Female subjects				Male subjects		
NI	Hypermobility	Ordinary mobility	Total	NI	Hypermobility	Ordinary mobility	Total
Control	7	38	45	Control	30	35	65
Case	3	21	24	Case	14	11	25
Total	10	59	69	Total	44	46	90
	OR	0.8			OR	1.5	
	CI 95%	0.2–3.4			CI 95%	0.6–3.8	

	Female subjects				Male subjects		
NI	Hypomobility	Ordinary mobility	Total	NI	Hypomobility	Ordinary mobility	Total
Control	28	38	66	Control	31	35	66
Case	42	21	63	Case	21	11	32
Total	70	59	129	Total	52	46	98
	OR	2.7**			OR	2.2$^{(*)}$	
	CI 95%	1.3–5.5			CI 95%	0.9–5.2	

$p < 0.1^{(*)}$, $p < 0.05^{*}$, $p < 0.01^{**}$.

significant. This may be due to the fact that the number of subjects in the hypermobile class were not as many as in the other two classes, and that hypermobility at level C7–T1 was not as frequent among female subjects as among male subjects. The hypomobile class shows a lack of the greater degree of mobility at level C7–T1, which is characteristic for the normal distribution of mobility in this part of the spine (1). There was a significant difference of mobility at level T3–T4 among cases (Table III, Fig. 3). The multiple regression analysis showed that increased mobility in motion segments T3–T4 and T4–T5 was significant determinants of NI. The overall fit expressed as R square showed that relative flexion mobility

Table VI. *Odds ratio comparing the influence of age on NI in the hyper- and hypomobility classes versus ordinary mobility.*

Age	NI	Ordinary mobility	Hyper-mobility	Hypo-mobility	Odds ratio	Hyper versus ordinary mobility	Hypo versus ordinary mobility
	Control	31	12	27	OR	3.0$^{(*)}$	3.1*
18–29 years	Case	6	7	16	CI 95%	0.9–10.6	1.1–8.8
	Control	25	16	20	OR	0.8	2.6*
30–45 years	Case	13	7	27	CI 95%	0.3–2.6	1.1–6.3
	Control	16	8	12	OR	0.2$^{(*)}$	2.2
46–65 years	Case	12	1	20	CI 95%	–	0.8–6.3
	Control	72	36	59	OR	1.0	2.5***
18–65 years	Case	31	15	63	CI 95%	0.5–2.0	1.4–4.3
Total		103	51	122	SRR	1.4	2.7

$p < 0.1^{(*)}$, $p < 0.05^{*}$, $p < 0.01^{**}$, $p < 0.001^{***}$.

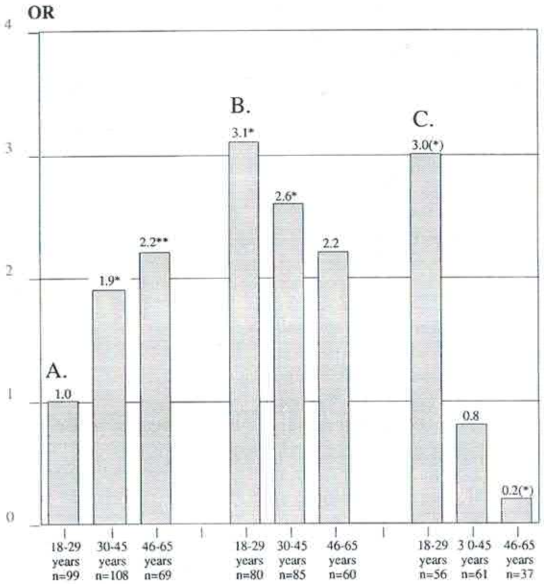

Fig. 4. A. Comparing influence of age on NI. B. Comparing influence of age on NI for the class with hypomobility at level C7–T1 versus ordinary mobility at level C7–T1. C. Comparing influence of age on NI for the class with hypermobility at level C7–T1 versus ordinary mobility at level C7–T1.

explained 10% of the variation in NI and 11% in NSI, respectively (Table IV). The inverse C7–T1 function can be looked upon as a change of pivot between motion segments C7–T1 and T1–T2. This change involves both decreased mobility at level C7–T1 and mostly also an increase at level T1–T2. However, the multiple regression analysis showed that decreased values at level T1–T2 were the strongest determinant of NI. Consequently, the risk for developing neck pain increased when both motion segments C7–T1 and T1–T2 showed lack of mobility. The inverse C7–T1 function showed the strongest relationships between flexion mobility and the different pain indices.

The results of this study indicate that several motion segments are involved in a complex fashion and relate to neck-shoulder pain. Norlander & Nordgren (11) have shown significant relationships between specific subjectively experienced symptoms and neck-shoulder pain in the three classes of mobility at level C7–T1. In the ordinary mobility class the specific symptom showing relationship to neck-shoulder pain was dizziness, in the hypermobile class it was pain in the region of the heart or the chest and in the hypomobile class it was headache. In subjects showing an inverse C7–T1 function mental stress showed a significant relationship to neck-shoulder pain. The symptoms in the hypomobile class and in the hypermobile class correspond well to the pain patterns described by Bogduk & Marsland (2) and defined as the upper and lower cervical syndromes with a dysfunction at levels C2–C3 and C5–C6, respectively. The inverse C7–T1 function shows a relationship to mental stress, which has been recognized as a factor in neck-shoulder pain by Holmström et al. (4). In conclusion, it has been shown that relative flexion mobility between C7 and T5 was an indicative factor, explaining 11% of the variation of musculo-skeletal neck-shoulder pain in the hypomobile class (Table IV) and 22% among subjects with inverse C7–T1 function. This indicates that the CTR technique may become a valuable complement in assessment of the patient with musculo-skeletal neck-shoulder pain.

Age has been shown by Homström et al. (4) to have relationship to neck pain. This was also confirmed in this study (Fig. 4A). However, the CTR classification model showed that the odds ratio was more elevated for young subjects, than for old for both hypomobile and hypermobile subjects as compared to subjects with ordinary mobility in the same age groups (Fig. 4B–C). This was an unexpected finding. In conclusion, decreased relative flexion mobility at level C7–T1 was considered a risk factor irrespective of age, while increased relative flexion mobility may be a protective factor in older age.

The results of this study indicate that mobility at level C7–T1 was an indicative factor of development of neck pain rather than the cause of pain. This hypothesis is also supported by the results in a 2-year follow-up study by Norlander et al. (12) showing that female subjects with an invariable inverse C7–T1 function showed an increased relative risk of developing more than 7 days of neck-shoulder pain during a 2-year follow-up period (RR 2.7, CI 95% 1.1–6.9) compared to subjects with a more variable function at level C7–T1. Also, the fact that hypomobile subjects showed a lowered odds ratio of 2.1 for neck pain during the previous 7 days compared to the results reported over 12 months may support mobility being an early sign of dysfunction, resulting in development of neck-shoulder pain in the future. Consequently an individual can show dysfunction of mobility before pain has developed.

The factor height showed no significant differences between female or male cases and controls in any class of mobility (Tables I–II). The factor height explained 1% of the variation in C7–T1 mobility among male subjects and 3% ($p < 0.05$) among female subjects. The correlation coefficients between genders were the opposite. This makes it difficult to explain the influence of the factor height on C7–T1 mobility, and further research is necessary.

Five male subjects were not included in the different analysis of the factor age because of missing results. This however did not change the result regarding comparisons between mobility classes and neck pain, as age was not included (Table V). It has some influence on the comparisons between the different age groups, but the total odds ratio was only lowered from 2.5 to 2.4 in the comparison between the hypomobility and ordinary mobility class (Table VI). For the hypermobile class the total odds ratio remains the same i.e. 1.0 (Table VI).

The value of the CTR technique is dependent on the repeatability of measurements. In a test-retest design situation the CTR technique has been shown to be well repeatable. In intratester repeatability the coefficient of variation was less than 5% and an intertester less than 8% (10). However, in the 2-year follow-up study (12), the individual variation of relative flexion mobility was found to be more pronounced than in a test-retest situation, which was a problem. In order to deal with this problem the variation was defined as normal biological variation, and the hypothesis was tested that lack of variation was a risk factor. The hypothesis was tested between a group with invariable inverse C7–T1 function versus a group with more variable function at level C7–T1 and the results showed that lack of variation was a risk factor for development of musculo-skeletal neck-shoulder pain (12).

Consequently, measurements with the CTR technique have to be repeated in order to determine whether the measured dysfunction remains and can develop into neck-shoulder pain or if it is occasional and can be regarded as normal biological variation of segmental flexion mobility. Further research in this area is necessary in order to evaluate whether the concept of classification can be used in screening examinations for predicting musculo-skeletal neck-shoulder pain.

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