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FLEXIBILITY OF THE SPINE: NORMATIVE VALUES OF GONIOMETRIC AND TAPE MEASUREMENTS

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ABSTRACT. A sample of 508 male and female white-collar and blue-collar employees aged 35 to 54 years were examined clinically to determine the reliability of spinal flexibility measurements using inclinometers and a tape measure, and to determine the normal values of cervical sagittal movements, lateral flexion, lumbar flexion and extension, trunk rotation and sidebending. Spinal flexibility decreased with advancing age, particularly among the blue-collar workers. Male predominance was observed in lumbar flexion and rotation and female predominance in cervical flexion-extension-movement. Spinal flexibility was negatively related to the experience of disabling pain. The strongest connections were between cervical flexion-extension-movement and neck pain, and between trunk sidebending and low back pain during the preceding year. The interobserver reliabilities were found to be generally good for all these measurements, and trunk sidebending showed the highest reliability coefficients. The intraobserver reproducibility (checked at a one-year interval) was acceptable only for cervical flexion-extension movement, cervical sidebending and trunk sidebending.

Key words: spinal flexibility, age, sex, occupation, low-back pain, neck pain, normative data.

INTRODUCTION

When comparing the clinical status with findings in time series and with observations by several persons, the lack of standards and normal values often becomes a problem. For example it is well-known that spinal mobility is related to age, but this is not always taken into account in disability rating schedules. Spinal motion is still a major determinant of impairment in many disability rating schedules used today.

This is why the present study focused on the flexibility of the spine and, in particular, on inclinometer measurements. The use of an inclinometer involving the pendulum principle was first described by Asmussen & Heeboll-Nielsen (1), and further developed by Loebl (11) and Troup et al. (18). The technique for separating hip from true lumbar spine motion components is possible with dual inclinometers (8). As far as the authors know, however, normative values of spinal motions measured by inclinometers with representative samples for clinical use are lacking. Burton & Tillotson (3) have presented reference values for normal regional lumbar sagittal mobility measured with a flexicurve. Dvorak et al. (5) have also presented a sample of 67 asymptomatic volunteers whose spinal ranges of motion were examined with a special device.

The aims of the present study were:

1) to determine the reliability of the spinal flexibility measurements by means of inclinometers and tape measure, and

2) to determine the normal values of spinal flexibility for different age and sex groups.

SUBJECTS AND METHODS

Subjects

This study was part of a comprehensive clinical survey of 594 persons aged 35–54 years working in four defined occupational and gender groups for the Helsinki City Council: truck drivers (blue-collar men), office or school cleaners (blue-collar women) and office employees such as clerks or civil servants (white-collar men and women). Of this sample, 508 persons (86%) participated in a clinical evaluation at the Rehabilitation Unit of the Invalid Foundation.

Methods

Histories of cervical and low-back pain were recorded using a standard questionnaire (9). The subjects were asked to classify separately their neck and low-back pain into one of the following categories:

1. Never suffered from pain in the neck or lower back;
2. Neck or low-back pain more than 12 months ago;
3. Neck or low-back pain during the previous 12 months but no disability due to the pain;

4. Limitation in daily tasks at work or in leisure time because of neck or low-back pain.

The instructions for the spinal flexibility measurements were mostly modified according to the methods of Keeley et al. (8) and Mellin (12, 13).

Cervical flexion and extension

The subject was seated on a chair without back support, keeping his feet on the floor. He was asked to focus in a mirror at a sight fixed between his eyes. The liquid inclinometer (MIE, Medical Research Ltd, London, GB) on top of the subject's head, attached by velcro to a cloth helmet, was then calibrated to zero. The subject inclined his head towards his breast as far as possible without moving his trunk. The flexion outcome was recorded. The head was returned to starting position and the inclinometer was again calibrated to zero. The subject inclined his head backwards as far as possible keeping his mouth open. The extension outcome was recorded. The sum of flexion and extension constituted the final result.

Cervical sidebending

The same position and cloth helmet were used as above. The inclinometer was rotated to a frontal direction. With the help of the mirror in front, the subject bent his head to the side in both directions without moving the trunk. The inclinometer was calibrated to zero after each measurement. The mean of left and right sidebends was the final result.

Cervical rotation

The gravitation inclinometer (Pendulum goniometer, MeDesign Ltd., London, GB) was attached to the helmet, and the subject was placed in the supine position. He was asked to rotate his head to the left as much as possible while lifting the head just a little bit above the plinth. At the end of the rotation the head was allowed to rest against the plinth and the outcome was recorded. The same procedure was performed to the right side. The mean of left and right rotations was the final result.

Lumbar flexion

While the subject was standing freely, his posterior superior iliac spines were palpated and a horizontal reference line was drawn uniting the spines. Spinal processes TH XII was identified by counting spinal processus down from C VII. The superior foot of the gravity inclinometer was attached to the tip of spinal processus TH XII. The superior foot of the liquid inclinometer was attached below the reference line uniting the posterior superior iliac spines. The maximal flexion outcome was recorded.

Lumbar extension

The subject had the same reference for the inclinometers as in the test of lumbar flexion, but he was in the prone position with hands up by the shoulders. He was asked to extend his upper limbs keeping the pelvis as low as possible. The degree of extension was recorded in the maximum arched position.

Trunk rotation

The subject was seated on a chair without backrest and fixed to the chair by a "safety belt". With both hands he kept a bar behind his neck, looking straight forward into the mirror. The waterscale with adjustable arms and compass inclinometer (Myrin, OB. Rehab-produkter, Sweden) were attached to the inferior level of the scapulae, keeping the compass inclinometer as close to the spine as possible. The inclinometer was calibrated to the zero position and the subject was asked to rotate to the right as far as possible. The range of motion was recorded and the same procedure was performed in the opposite direction. The mean of left and right rotations was the final result.

Trunk sidebending

The subject was standing against a wall with his feet 15 cm apart. The position of the tip of his index fingers was marked on the skin of both thighs. The subject was asked to bend maximally to the right and left sides while maintaining wall contact. The maximal reach of the tip of the index fingers was marked on the skin of the thighs on both sides. The distance between the upper and lower marks were measured with a nonflexible tape in millimeters. The mean of left and right sidebends was the final result.

Procedure for the tests of reliability and reproducibility

The interobserver reliability measurements were made by two trained physiotherapists at one-week intervals with 24 subjects in random order. Of the 24 subjects 17 were twice measured for lumbar flexibility, and all were tested for cervical flexibility. None of the subjects suffered from neck pain or low-back pain.

The intraobserver reproducibility was checked with measurements made at a one-year interval by the same physiotherapist. The subjects had no low-back pain or neck pain. We were attempting to find such measurements as would be fairly reproducible in healthy subjects over a period of several months at least.

Statistical methods

The reliability and reproducibility of the flexibility measurements were assessed with the reliability coefficient (19). A coefficient greater than 0.75 is considered to represent excellent reliability, coefficients between 0.4 and 0.75 represent fair to good reliability, and coefficients below 0.4 represent poor reliability (6, 10). The presence of a systematic difference between the measurements was investigated using the paired t-test.

The adjusted means of the flexibility measurements were estimated on the basis of a general linear model (4). Age (years), sex (male, female), occupation (white-collar, blue-collar) and the type/level of pain were entered in the multifactorial models as explanatory variables.

RESULTS

The interobserver reliability of spinal flexibility measurements was evaluated by two physiotherapists at one-week intervals. All reliability coefficients were fairly high (Table I). The highest value was found for trunk side-bending ($r = 0.91$), and the lowest values (but nevertheless fairly good) were noted for

Table I. *Interobserver reliability of spinal flexibility measurements by two testers at an interval of one week*
N = number of measurements.
$\bar{x}$ = mean value of all measurements (degrees except mm for trunk sidebending).
r = reliability factor (Winer 1971).
D$\bar{x}$ = change of means.
DSD = deviation of D$\bar{x}$
t = *paired t*-test (df = n−1).
p = statistical significance of systematic shift.

	N	$\bar{x}$	*r*	D$\bar{x}$	DSD	*t*	*p*
Cervical flex + ext	48	115	0.69	2.4	20.8	0.81	0.42
Cervical sidebending (left + right)	48	71	0.79	1.6	11.0	1.03	0.31
Cervical rotation (left + right)	48	140	0.86	2.9	16.6	1.20	0.24
Lumbar flexion	34	44	0.61	−3.41	8.21	2.42	0.02
Lumbar extension	34	18	0.63	−0.21	6.39	0.19	0.85
Trunk rotation (left + right)	34	103	0.79	3.32	11.82	1.64	0.11
Trunk sidebending (Left + right)	34	413	0.91	2.15	28.91	0.43	0.67

Table II. *Intraobserver reproducibility of spinal flexibility measurements by the same physiotherapist at an interval of one year*
n = number of subjects.
$\bar{x}$ = mean value of the two measurements.
p = statistical significance of the error level.
r = reliability factor (Winer 1971).
* = the mean of left and right movement.

		1st test		2nd test			
	n	$\bar{x}$	SD	$\bar{x}$	SD	*p*	*r*
Cervical flex + ext	99	120	16	120	16	0.58	0.68
Cervical* side bending	99	37	6	36	5	0.38	0.61
Cervical* rotation	99	75	7	80	7	0.000	0.37
Lumbar flexion	93	46	9	31	22	0.000	−0.07
Lumbar extension	93	16	6	11	9	0.000	0.07
Trunk* rotation	93	47	9	51	7	0.000	0.48
Trunk* sidebending	93	186	34	191	31	0.013	0.81

Table III. *Adjusted mean values (degrees) of cervical mobility according to age, sex, occupation, and previous neck pain*

Explanatory factor	Number of subjects	Extension + flexion	Side-bending	Rotation
Age[1]				
35–39	127	126	38	77
40–44	148	120	38	76
45–49	113	117	35	74
50–54	120	113	34	70
p-value		< 0.001	< 0.001	< 0.001
Sex[2]				
Male	254	116	36	75
Female	254	122	37	74
p-value		< 0.001	0.006	0.29
Occupation[3]				
White-collar	189	118	37	75
Blue-collar	319	120	36	74
p-value		0.22	0.53	0.04
Previous neck pain[4]				
Never any pain	125	122	38	75
Pain more than 12 months ago	37	117	36	73
Pain during previous 12 months, no disability	212	122	37	74
Disabling pain during previous 12 months	134	113	35	73
p-value		< 0.001	0.02	0.08

Class-specific mean values adjusted for [1]sex and occupation; [2]age and occupation; [3]age and sex; [4]age, sex and occupation.

lumbar flexion ($r = 0.61$) and extension ($r = 0.63$). No statistically significant shifts between the two measurements were observed, with the exception of lumbar flexion ($p = 0.02$).

The intraobserver reproducibility of the flexibility measurements (Table II) at an interval of one year showed again good values of the reliability coefficient for cervical flexion-extension movement ($r = 0.68$), cervical sidebending ($r = 0.61$) and particularly for trunk sidebending ($r = 0.81$), and a fair value for trunk rotation ($r = 0.48$). The reliability of the other measurements was poor.

Occurrence of previous neck pain or low-back pain was considered a possible confounding factor. That is why the subjects were grouped according to occurrence of pain and disability into four groups (Tables III and IV). The results indicated that the ones who reported disabling pain in the neck during the previous 12 months also had a significantly lower range of motion in cervical flexion-extension movement, and also somewhat lower cervical sidebending than the others.

In a similar manner, the significance of previous low-back pain for trunk flexibility was studied. For the lumbar and trunk flexibility a statistically significant variation was observed only for trunk sidebending ($p < 0.001$): subjects with disabling pain during the previous 12 months had lower range of motion than others (Table IV).

There was a clear inverse relationship between age and cervical flexibility, and this was noted also after adjustment for sex and occupation ($p < 0.001$) (Table III). Female predominance was observed in cervical flexion-extension-movement ($p < 0.001$) and in side-bending ($p = 0.006$), but not in rotation. There was also a slight decrease in the range of motion of cervical rotation in blue-collar workers compared to white-collar workers ($p < 0.05$).

Lumbar flexion also showed over a 10% decrease with age when comparing the youngest and the oldest examinees (Table IV). This variation according to age was evident even after sex and occupation adjustments ($p < 0.001$). Men had greater ranges of motion than women ($p < 0.001$). No significant difference was observed between white-collar and blue-collar occupations with respect to the lumbar flexion ($p = 0.44$).

As for lumbar extension, no differences were observed between the sexes. However, this was the only measurement where blue-collar workers showed a greater range of motion than white-collar workers, and this difference remained significant after adjusting for age and sex ($p < 0.001$) (Table IV).

Table IV. *Adjusted mean values of lumbar extension (degrees), flexion (degrees), side-bending (millimetres) and rotation (degrees) according to age, sex, occupation, and previous low-back pain*

Explanatory factor	Number of subjects	Extension	Flexion	Side-bending	Rotation
Age[1]					
35–39	127	17	50	200	48
40–44	148	16	47	193	47
45–49	113	15	46	182	46
50–54	120	14	43	163	43
p -value		0.001	< 0.001	< 0.001	< 0.001
Sex[2]					
Male	254	15	48	187	49
Female	254	16	44	183	43
p-value		0.12	< 0.001	0.19	< 0.001
Occupational[3]					
White-collar	189	14	46	190	48
Blue-collar	319	17	46	182	45
p-value		< 0.001	0.44	0.02	< 0.001
Previous low-back pain[4]					
Never any pain	119	17	46	191	47
Pain more than 12 months ago	48	16	47	189	45
Pain during previous 12 months, no disability	178	15	47	190	47
Disabling pain during previous 12 months	163	15	47	175	45
p-value		0.31	0.15	< 0.001	0.33

Class-specific mean values were adjusted for [1]sex and occupation; [2]age and occupation; [3]age and sex; [4]age, sex and occupation.

The greatest decrease, a total of 19%, from the youngest to the oldest age group in spinal mobility was observed in trunk sidebending, also after adjusting for sex and occupation (Table IV). Male predominance was observed in rotation ($p < 0.001$), but not in side-bending when age and occupation were adjusted for. Trunk rotation and somewhat trunk sidebending showed differences between the occupational groups, blue-collar workers having a lower range of motion.

The normative data of the cervical spine flexibility in different age, sex and occupation groups are presented in Table V and for the thoraco-lumbar spine in Table VI.

DISCUSSION

The interobserver reliability of inclinometer and tape measurements proved to be overall good in this study. The lowest coefficient of reliability was found for lumbar flexion ($r = 0.61$), but even this value can be regarded as fairly good. Lumbar flexion is perhaps the most commonly used measure of spinal flexibility, and thus it is of special interest also in matters of reproducibility.

The intraobserver reproducibility testing was made at a one-year interval. This means the reproducibility no longer depended solely on the technical performance of the measurement but even more perhaps on biologic variation. This would explain why the reliability coefficients differed a great deal from the interobserver measurements made at a one-week interval. The results suggest that if we are interested in changes over a short period of time, any of the tested measurements can be considered acceptable. If we are interested in spinal flexibility changes over the long run, seeking for example a tool for follow-up measurement in occupational medicine, we should rely more on the three flexibility measurements: cervical extension + flexion, cervical sidebending and trunk sidebending.

Another important question is what population the tested subjects represent. The target population in this study comprised working people in groups of a given age and occupation. This implies they cannot have

Table V. *Cervical flexion-extension (degrees; $\bar{x}$ and SD), sidebending and rotation (mean of the left and right movements) according to age, sex and occupation*

		MEN						WOMEN							
		Blue collar		White collar		Total		Blue collar		White collar		Total		ALL	
	Age	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Flexion + extens.	35–39	123	17	119	14	121	16	134	20	127	17	131	19	126	18
	40–44	117	17	120	16	118	16	125	15	112	18	121	19	119	17
	45–49	110	20	116	15	112	18	123	17	122	17	122	17	118	18
	50–54	110	16	111	12	110	14	113	19	113	22	113	19	112	17
	35–54	116	18	117	15	116	17	123	19	120	19	122	19	119	18
Side-bending	35–39	39	5	37	5	38	5	40	5	39	5	40	5	38	5
	40–44	37	5	37	6	37	5	38	6	37	5	38	6	37	5
	45–49	32	8	37	5	34	7	37	4	37	6	37	5	36	6
	50–54	33	6	34	5	34	6	33	6	36	4	34	6	34	6
	35–54	36	6	36	5	36	6	36	6	38	5	37	6	37	6
Rotation	35–39	77	7	78	6	77	6	77	6	78	8	77	7	77	7
	40–44	75	9	75	7	75	9	75	8	73	7	74	8	75	8
	45–49	71	12	77	4	73	10	74	9	75	7	74	8	74	9
	50–54	72	7	74	7	72	7	67	9	74	7	68	9	70	8
	35–54	74	9	76	6	75	8	73	9	75	7	74	8	75	8

Table VI. *Lumbar flexion and extension (degrees; Th XII-SI; $\bar{x}$ and SD), trunk rotation (degrees; mean value of left and right rotation) and trunk sidebending (mm; mean value of left and right sidebending) according to age, gender and occupation*

		MEN						WOMEN							
		Blue collar		White collar		Total		Blue collar		White collar		Total		ALL	
	Age	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Lumbar flexion	35–39	52	8	50	9	51	9	51	8	46	12	48	10	50	10
	40–44	47	10	50	8	48	10	44	9	40	11	43	10	46	10
	45–49	46	8	47	9	46	9	42	9	43	12	43	10	44	10
	50–54	46	10	45	10	45	10	41	10	44	8	42	10	43	10
	35–54	48	10	49	9	48	9	41	10	44	8	44	10	46	10
Lumbar extension	35–39	17	7	14	6	16	6	20	8	17	4	18	7	17	7
	40–44	18	8	14	5	16	7	17	7	13	5	16	6	16	7
	45–49	15	6	13	6	14	6	15	8	14	5	14	7	14	7
	50–54	15	6	11	4	14	6	16	7	13	4	15	7	16	7
	35–54	16	7	13	5	15	6	17	8	15	5	16	7	16	7
Trunk rotation	35–39	49	9	53	9	51	9	45	7	48	10	46	9	49	9
	40–44	51	9	53	10	52	9	43	9	41	7	43	8	47	10
	45–49	43	10	54	11	47	12	43	10	47	7	44	9	46	11
	50–54	45	9	52	7	48	9	37	8	38	9	38	8	42	10
	35–54	47	10	53	9	50	10	42	9	44	9	43	9	46	10
Trunk Side-bending	35–39	200	41	197	36	199	39	202	33	205	51	203	42	201	41
	40–44	190	31	200	29	194	30	192	43	181	34	187	40	191	35
	45–49	167	34	195	34	177	36	175	30	189	40	180	35	179	35
	50–54	171	44	184	37	175	41	147	34	165	27	150	37	162	39
	35–54	184	39	195	34	188	38	177	41	190	43	182	42	185	40

any severe spinal pathology or symptoms, and roughly a third were completely symptom free. Reported pain differentiated the subjects with respect to spinal flexibility, but perhaps less than expected. Of all the measurements studied, only cervical flexion + extension, cervical sidebending and trunk sidebending were significantly reduced among the symptomatic subjects reporting disabling pain. Mellin (14) also found statistically significant correlations between spinal mobility measurements and concurrent low-back pain, the correlation being highest for lateral flexion measured by tape. Burton (2) reported an increased relationship between a history of low-back pain and reduced mobility of the lumbar spine in the sagittal plane.

However, we considered it proper to pool all the subjects together when reporting our normative data. The main argument is that if we are interested in the spinal mobility of working people, some of them do have symptoms in any case, because low-back pain and neck pain are so common.

Moll & Wright (15) observed that thoraco-lumbar flexion, extension and lateral flexion showed an increase in mean spinal mobility from the age of 15 until 25 years, which was followed by progressive decrease with advancing age. In our study this initial increase of spinal mobility could not be verified, as the youngest in our sample were already 35 years of age. Moll & Wright's (15) observation is a reminder, however, that one cannot make a linear approximation of our results into the younger age groups.

A sex difference was not so clear in our sample as in Moll & Wright's (15) study, where male mobility exceeded female mobility in lumbar extension and flexion by 7–11%. In the present study, male predominance over female was observed in lumbar flexion but not in extension. Moll & Wright (15) have also reported better mobility in lateral flexion for women, but we could not confirm that either. In trunk rotation male mobility exceeded female mobility in the present study.

Different patterns of spinal mobility between the sexes have been reported also by other workers (17). Discrepancy between the results is hard to explain, but the measurement position may be a critical issue (e.g. standing or lying prone), as well as other details in the technical performance of the measurement.

Occhipinti et al. (16) reported trunk rotation values with a wide range, 28–61° to the right and 29–61° to the left. The subjects were all men ($n = 200$), mean age 40 years. Our results match fairly well with these figures (a mean value of 50°).

Orthopedic text-books usually give mean figures for cervical movements as follows: anterior flexion 45°, extension 50–60°, rotation 60–80° and lateral flexion 40°. Our own results match these values fairly well, too. We preferred reporting the whole sagittal movement, anterior flexion and extension counted together, because defining the initial position of the neck is somewhat arbitrary.

One may ask where we need these objective measurements and normal values. We would like to answer according to Helliwell et al. (7) that the value of objectivity and normal values depends not only on the obvious direct advantage based on increased accuracy of the assessment, but also on the indirect advantage of individual correction to be made for age and sex. Only reliable spinal flexibility measurements can contribute to the diagnostic and therapeutic assessments.

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