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The importance of spinopelvic parameters in patients with lumbar disc lesions

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Abstract Using a special software program we measured spinopelvic parameters on digitised radiographs of the entire spine and the pelvis of 50 patients with lumbar disc herniation and compared these with the same measurements on 30 healthy subjects. In the disc hernia group the patients had a relatively straight spine in the sagittal plane. The sacrum was more vertical, and the value of the lumbar lordosis was lower, as was the amplitude of the spinal curvatures, when compared with those of the healthy group. This results in a higher gravitational compressive force which may, in turn, lead to progressive degeneration of the discs. The anterior shift of the line of gravity may cause spinopelvic instability, and contraction of the posterior spinal muscles in trying to balance this disturbed spatial relationship may produce back pain.

Résumé Avec un logiciel spécial nous avons mesuré des paramètres rachidiens et pelviens sur les radiographies numérisées de 50 patients avec hernie discale lombaire et de 30 sujets sains. Dans le groupe avec hernie discale les patients avaient une colonne vertébrale relativement droite dans le plan sagittal. Le sacrum était plus vertical, la lordose lombaire plus discrète et donc l'amplitude des courbures vertébrales plus faible en comparaison du groupe sain. Cela peut mener à la dégénérescence progressive des disques, par suite d'une plus grande force compressive gravitationnelle. La modification de la ligne de gravité antérieure peut causer l'instabilité rachidienne – pelvienne. Les muscles vertébraux postérieurs peuvent avoir tendance à corriger ce déséquilibre spatial ce qui peut causer des douleurs postérieures.

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Introduction

The development of low back pain can be associated with certain alterations in the sagittal shape of the spine [1, 2, 3, 4, 5, 6, 7, 8]. The relationships between the gravity line of the body and some spinal parameters have often been examined [2, 5, 6], and attention is being directed toward the importance of spinopelvic balance.

In this study we examined the spatial relationship of the spine and the pelvis in patients with disc herniation. We used healthy subjects as controls in order to assess whether there was any difference in the spinopelvic relationship in the sagittal plane between the two groups.

The assessment of radiographs, particularly when several variables are involved, is often long and tedious. Therefore, new software was developed in our laboratory during "International Cooperation in 1998" to allow computer-assisted measurements on sagittal plan radiographs.

Material and methods

Healthy subjects and patients

We studied lateral radiographs of the entire spine of 30 healthy subjects (Table 1). Inclusion criteria for these adult volunteers were age (30–39 years), no previous spine surgery, no spinal pathology, and no history of hip or back pain or other local problems. After having given informed consent, these volunteers were examined clinically by two independent orthopaedic surgeons and underwent radiographic examination in order to establish the normal values.

The radiographs were taken in the radiology department of the Mulhouse Hospital CHU in France. In all these 30 normal subjects, left-to-right standing 30×90 cm lateral and anteroposterior radiographs of the pelvis and the entire spine were taken by the same radiographer, using the same X-ray machine, and with a fixed cassette to X-ray source distance of 185 cm. The right side of the subject was placed against the cassette and a requirement for the standing radiographs was the visibility of both femoral heads. The subjects were positioned and then asked to stand straight, but relaxed. The knees were extended as much as possible with the femurs parallel to the film. The arms were held out a little below chest level and were supported by the back of a chair.

Table 1 General data of the subjects and patients

Pathology		Intervertebral disc hernia	"Normal" subjects
Age (years)	Mean±SD	47.70±14.15	34.33±3.06
Sex	Women/men	22/28	15/15
Level of pathology (no. cases)	L1/L2		
	L2/L3		
	L3/L4	10	
	L4/L5	21	
	L5/S1	19	
Cultivated some sport	Percentage of patients	34%	69%
Body mass index	Body weight in kg/height in m^2	25.42±2.4	24.61±2.2

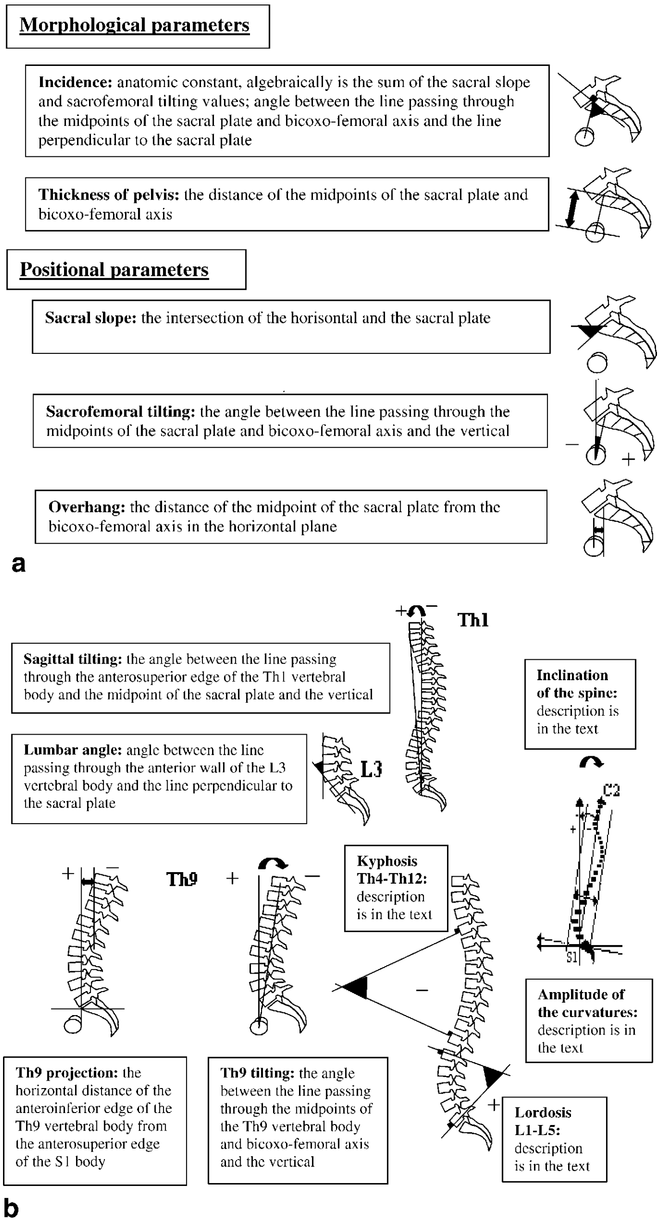


Fig. 1 **a** Pelvic parameters, **b** spinal parameters

We investigated 50 patients (28 men and 22 women) with intervertebral disc herniation (Table 1). The inclusion criteria for these patients were neurological symptoms, evidence of disc herniation confirmed by magnetic resonance imaging, and no previous spine surgery. These patients were examined and treated in four French orthopaedic centres. They were examined clinically by two independent orthopaedic surgeons, and radiographs were taken preoperatively.

All had signed a consent form allowing their clinical data to be used for research. In all the centres the radiological protocol was the same as described for the normal group. All the radiographs were sent to the laboratory of Biomechanics of Ecole National Superieure d'Arts et Metier (EMSAM), Paris, together with a completed "checklist" for each patient.

After scanning the lateral radiographs (Vidar-12 radiograph scanner, 75 dpi resolution, 12-bit grey scale), we used SpineView software to analyse the 13 independent variables listed below. The validation protocol for the software measurements has been published elsewhere [9].

Measured variables

The measured variables were divided into two groups, pelvic and spinal parameters. The pelvic morphological and positional parameters were defined according to Duval-Beaupere [7]. Short descriptions of the variables are presented in Fig. 1.

The software calculates the lordosis and kyphosis by using the angles of intersection of the lines perpendicular to the anterior wall of the corresponding vertebrae [9]. Two additional parameters were also considered [12]: the overall *inclination* of the spine, which is the angle between the vertical and the best-fitted straight line through the anterior side of the vertebrae from L5 to C2, and the *amplitude* of the spinal curvatures. This is the sum of the maximum distances between the anterior side of the vertebral bodies on top of the kyphosis and the lordosis respectively, and the best fitted straight line through the anterior side of the vertebral bodies from L5 to C2.

The software program calculates angles in degrees. Distances are expressed as percentages of the length of the sacral plate in order to avoid the effect of X-ray beam divergence.

Statistical analysis

Commercial statistical software (StatView4.5) [10] was used to analyse differences between the normal group and the disc hernia group. When there was a normal distribution, Student's *t*-test was used to analyse the difference between the two groups, and the traditional Pearson correlation test was used to assess the correlation between all variables. The significance of the correlation coefficients was tested by Fischer z-test, and statistical significance was set at a probability level of 5% or less.

Results

Intergroup comparison of measured variables

As shown in Figs. 2, 3, and 4, normal distribution was found for all measured variables. However, in the disc hernia group as compared with the normal group, a small

Table 2 Significant correlations between variables. Numerical value is the correlation coefficient while the stars (*) denote the strength of the significance: *P*<0.001***, 0.001<*P*<0.01**, 0.01<*P*<0.05*

Correlations	Intervertebral disc hernia	Normal
Incidence of the pelvis vs sacral slope		0.625***
Incidence of the pelvis vs sacrofemoral tilting		0.753***
Incidence of the pelvis vs L1–L5 lordosis		0.591 **
Sacral slope vs overhang	–0.689***	
Sacral slope vs lumbar angle		0.793***
Sacral slope vs L1–L5 lordosis	0.675***	0.663***
T9 projection vs amplitude	–0.745***	–0.547 **
Inclination vs L1–L5 lordosis	–0.66***	
Inclination vs sagittal tilting	0.609 **	
Amplitude vs kyphosis	–0.843***	–0.704***
L1–L5 lordosis vs lumbar angle	0.615***	
T9 tilting vs sagittal tilting	0.748***	0.609***

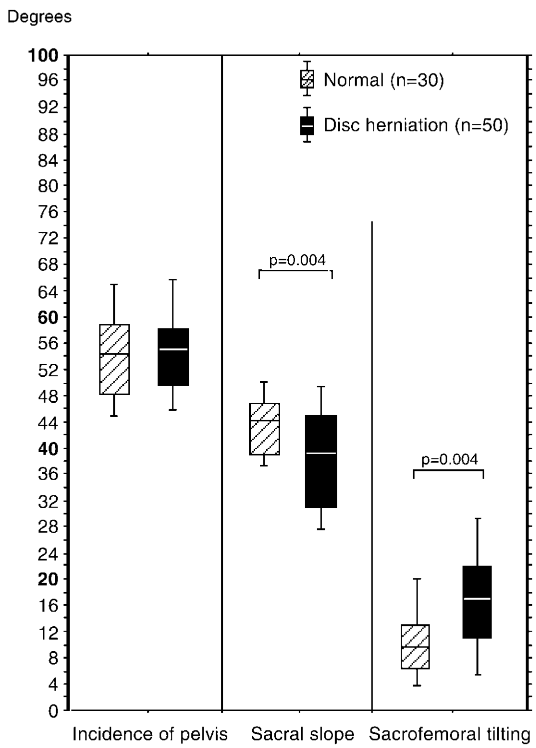


Fig. 2 Pelvic parameters in the different examined groups. The means, 90th percentiles, and significant differences are indicated

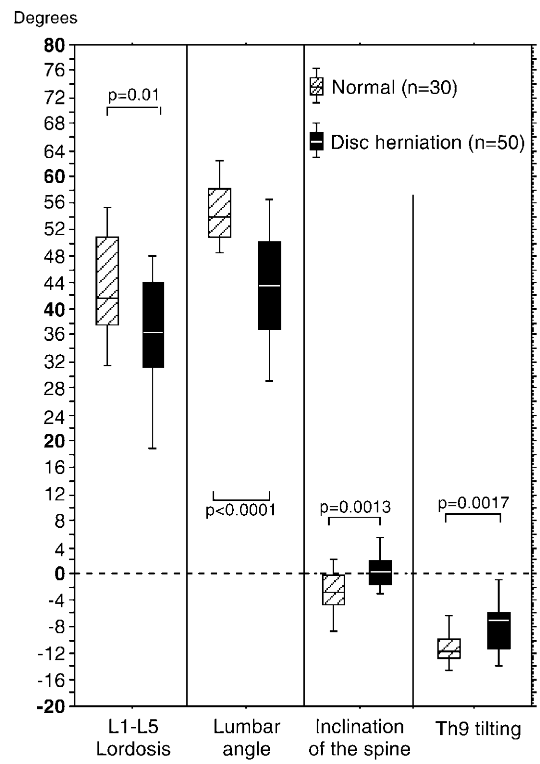


Fig. 3 Some spinal parameters in the different examined groups. The means, 90th percentiles, and significant differences are indicated

sacral slope, lumbar angle, L1–L5 lordosis, and amplitude of the curvatures were found. The extent of sacrofemoral tilting, the overhang, the T9 projection, the T9 tilting, and the inclination of the spine were higher in the patient group than in the asymptomatic subjects. There was no significant difference between the groups as regards the incidence, the thickness of the pelvis, the degree of T4–T12 kyphosis, and the sagittal tilting angle.

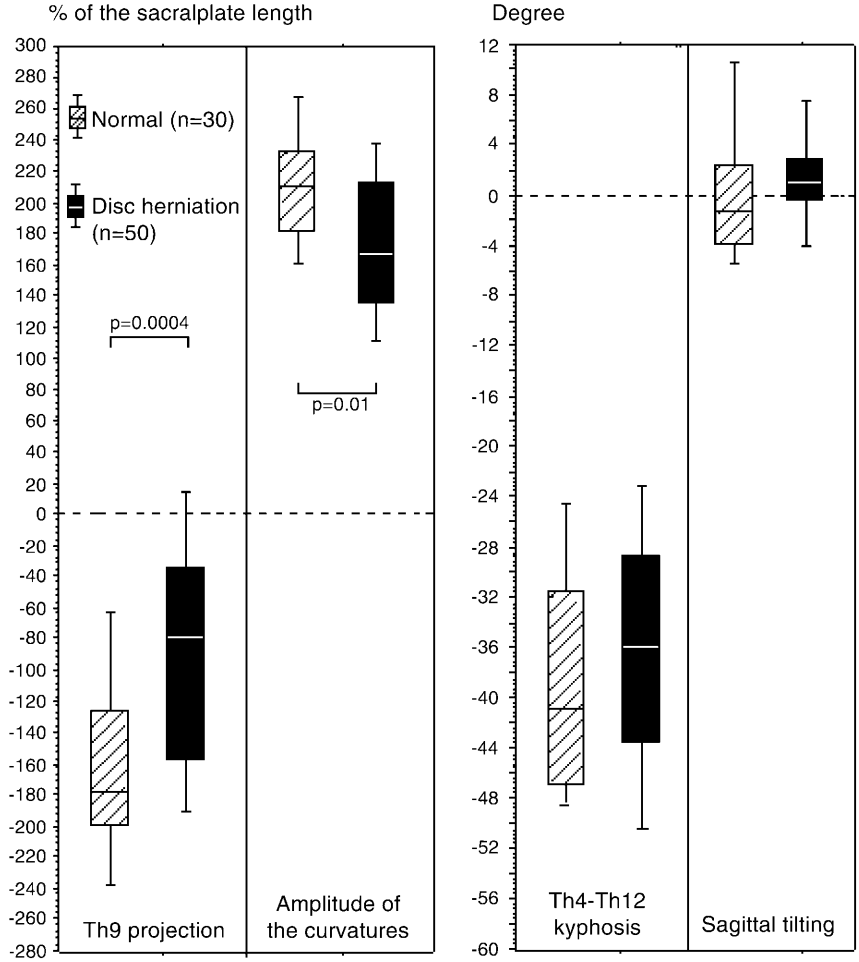
Correlations between measured variables

Table 2 lists the significant correlations between the various pelvic and spinal parameters. The numerical value is the correlation coefficient while the stars denote the strength of the significance (*P*<0.001***, 0.001<*P*<0.01**, 0.01<*P*<0.05*).

Discussion

According to the investigations of Duval-Beaupere [7, 8] the centre of gravity is located at about the level of the T9 vertebra. The gravity line of the body passes through many vertebrae and “leaves” the spine at the sacral promontory [11]. The sacrum is a double lever arm, which is supported by the sacroiliac joint through which forces pass from the spine to the pelvis and legs. The posterior arm of the sacrum is fixed to the spine and pelvis by the sacroiliac and lumbosacral ligaments.

Fig. 4 Some spinal parameters in the different examined groups. The means, 90th percentiles, and significant differences are indicated



The small sacral slope high sacrofemoral tilting found in the disc herniation group suggest that the spatial orientation of the sacrum is more vertical than in the normal group. The small degree of L1–L5 lordosis, the lumbar angle, and the amplitude of the curvatures, together with the high value of the inclination of the spine, show that the sagittal shape of the spine in these patients is straight with only small curvatures (Fig. 5). In this situation the compressive force component of gravity increases and these greater compressive forces accelerate the degeneration of the disc. This increase of the compressive forces is probably one of the many pathognomonic conditions that lead to herniation. Therefore, this pathology occurs at about 50 years of age and not earlier in life.

The hereditary factor

The incidence correlated well with the sacral slope and lordosis in the healthy subjects. This means that there is a greater incidence associated with an increased lordosis or vice versa, and this suggests that the spine and pelvis supported by the legs are balanced in the sagittal plane. On the other hand, the poor correlation between the incidence and the lordosis confirms a disharmonious spino-pelvic relationship in patients with disc herniation. The high value of T9 tilting and T9 projection suggest that the gravity line shifts anteriorly. This produces "permanent contraction" of the posterior spinal muscles in an

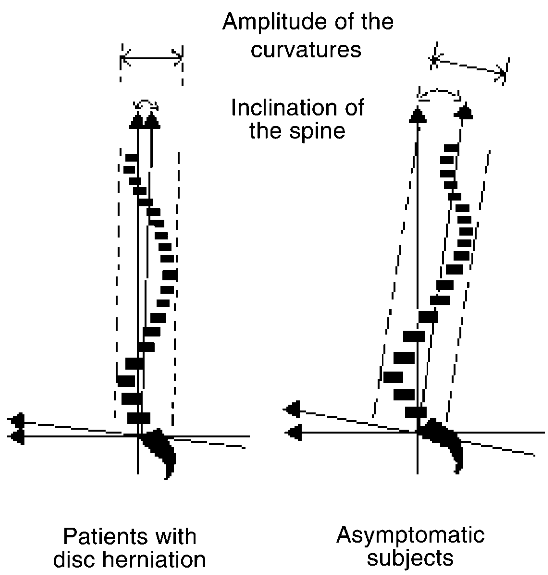


Fig. 5 Sagittal spinal alignment of the disc hernia group as compared with the normal group

attempt to restore the sagittal balance [1]. The resulting fatigue of these muscles may be the cause of severe back pain [2, 3, 4]. It is important to examine the sagittal balance of a patient before any operation is performed in order to avoid any postoperative sagittal imbalances. If the surgeon uses an interbody implant after discectomy to restore any intervertebral space narrowing, loss of the lordosis can be avoided. Computerised analysis permits multicentric data registration and the possibility of using telediagnosis, as well as consultation between specialists.

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