

Axially Loaded Magnetic Resonance Image of the Lumbar Spine in Asymptomatic Individuals

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Study Design. For this study, 43 asymptomatic individuals underwent magnetic resonance imaging of the lumbar spine in both supine psoas-relaxed position and supine axial compression in extension. The change in dural cross-sectional area between positions at each disc level was calculated.

Objectives. To evaluate the effect of axial loading on asymptomatic individuals, as compared with the effect on patients who have clinical signs of lumbar spinal canal stenosis, and to assess the effect that different magnitude and duration of the applied load have on the dural cross-sectional area.

Summary of Background Data. Degenerative changes in the spine are found in both symptomatic and asymptomatic individuals. A study of patients with suspected clinical lumbar spine encroachment examined in both psoas-relaxed position and axial compression in extension with computed tomographic myelography or magnetic resonance imaging of the lumbar spine is reported. A significant decrease in dural cross-sectional area was found, respectively, in 80% and 76% of the patients.

Methods. The study subjects underwent magnetic resonance imaging examinations in both psoas-relaxed position and axial compression in extension. The examination of the subject under axial compression in extension was performed with the lumbar spine in a supine position using a compression device. Degenerative changes in and adjacent to the spinal canal were registered. The dural cross-sectional areas were determined for psoas-relaxed position and axial compression in extension, then compared. In seven reexamined individuals, the dural cross-sectional area was calculated after an axial load corresponding to 25% and 50% of their body weight and a loading time of 5 to 60 minutes.

Results. A significant decrease in dural cross-sectional area from psoas-relaxed position to axial compression in extension was found in 24 individuals (56%), most frequently at L4–L5, and increasingly with age. In four individuals (5 disc levels), a decrease in dural cross-sectional area to less than 100 mm² from psoas-relaxed position to axial compression in extension was found. In seven reexamined individuals, a significant decrease in dural cross-sectional area was found: in five after 5 minutes load of 25% of their body weight, and in two with 50% of their body weight.

Conclusions. Using magnetic resonance imaging, a significant decrease in dural cross-sectional area after axial loading was found less frequently in asymptomatic than in symptomatic subjects. The decrease was more frequent at L4–L5, and increasingly with age. The load

should be 50% of the subject's body weight applied for at least 5 minutes. [Key words: asymptomatic, axially loaded, CT, low back pain, lumbar spine, MR, spinal stenosis] **Spine 2001;26:2601–2606**

Low back pain with or without sciatica currently is one of the most common medical problems in the Western world, afflicting approximately 80% of all individuals during their lifetime.^{2,8,9} One reason for back pain is lumbar spinal canal encroachment. This entity might initiate neurogenic claudication, characterized by pain and neurologic symptoms in the lower extremities elicited by walking, standing, or other positions such as extension. Typically, these patients experience fewer symptoms when bending forward, squatting, or lying supinely with hips flexed.

A detailed analysis of the conditions in the lumbar spinal canal is mandatory before patient treatment is decided. Computed tomography (CT) scan and magnetic resonance imaging (MRI) have, to a large extent, replaced myelography as a diagnostic tool. However, examining patients in the position in which they normally experience their symptoms poses some problems. Recently, a device has been constructed that makes it possible to perform CT scan and MRI of the lumbar spine with the subject in an axially loaded position (axial compression in extension [ACE]). By use of this device, it has been shown that the dural sac cross-sectional area (DCSA) at the disc levels frequently decreases from conventional psoas-relaxed position (PRP) to an axially loaded position (ACE) in patients with a suspected lumbar spinal stenosis.^{3,18,21}

The results from several studies on conventional radiography, CT scan, and MRI conducted with asymptomatic individuals have been published. In a high percentage of these individuals, disc degeneration, bulging, or protrusions are described.^{1,6,7,11,17,20}

The current study aimed to examine asymptomatic individuals with MRI during axial loading of the lumbar spine in a supine position, comparing the effect of the load on the structures in the spinal canal in these subjects with that found in symptomatic individuals, and to evaluate the effects that different magnitudes of axial loading and different lengths of loading time have on the DCSA.

■ Material and Methods

In this study, 43 healthy individuals (22 women and 21 men), ages 20 to 60 years, were examined. The distribution in terms of different age groups is shown in Table 1. None of these individuals had any history of low back pain or sciatica. Of the

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Table 1. Number of Examined and Reexamined Individuals in Different Age Groups*

	Age (years)				Total Σ
	20–29	30–39	40–49	50–59	
Female	5	5	7 (1)	5 (2)	22
Male	6	5	5 (2)	5 (2)	21
Total	11	10	12 (3)	10 (4)	43 (7)

* Number of reexamined individuals in parentheses.

43 individuals, 7 (3 women and 4 men) were selected for reexamination (Table 1).

The MRI was performed on a 1.0-T system (Magnetom Impact; Siemens, München, Germany) using a surface coil. All the subjects were first examined during MRI in a supine psoas-relaxed position with slight flexion in the hips and knees (PRP). In this position, sagittal T2-weighted as well as axial T1- and T2-weighted turbo spin-echo sequences were performed. The repetition time (TR)/echo time (TE) was 3500/105 and 4200–6262/119–130, respectively, for T2-weighted sagittal and axial images. The TR/TE was 875–950/12 for T1-weighted axial images. The slice thickness was 4 mm, and the field of view was 160–320 × 320 for sagittal images and 219–270 × 250 for axial images. The imaging matrix was 126–256 × 256 and 210–256 × 256, respectively, for sagittal and axial images. The number of excitations was between two and four for both sagittal and axial images.

The disc levels from L3 to S1 were examined. The box for transverse slices was placed parallel to the disc examined.³ To evaluate the nerve root in the recess and foramen, the box was placed more cranially when the T1-weighted sequences were performed than when the T2-weighted sequences were performed.

Axial loading of the spine was performed using a nonmagnetic compression device and a harness (Figure 1) (DynaWell, DynaMed AB, Stockholm, Sweden).^{3,18,21} The patient was lying supine with extended hips and knees. To prevent flexion of the spine during compression, a cushion was placed behind the lumbar spine. The feet were positioned against a footplate on the compression device. The harness worn by the patient was attached to the compression device using side straps, which were tightened for axial loading of the lumbar spine. The load, regulated by tightening or loosening adjustment knobs on the compression device, was registered on indicators.

According to previous disc pressure measurements,^{10,13} the chosen load was approximately 50% of the subject's body weight, with equal load distribution on both legs. The load was applied for at least 5 minutes, after which axial T1- and T2-weighted sequences were performed.

Seven individuals were reexamined on two different occa-

sions—in three individuals after a load of 25% of their body weight and in two individuals after a load of 50% of their body weight. On both occasions axial T1- and T2-weighted sequences were conducted after 5, 20, 40, and 60 minutes of axial loading. The changes in the spinal canal from L3 to L5 were evaluated.

The DCSA was determined by using a measurement program on a digital image view station (Magic View 1000; Siemens). The image selected was the one in which the area seemed to be the smallest on each disc level. By carefully inspecting the surrounding soft and skeletal tissues as well as the spinal canal, this ensured selection of the most comparable images during PRP and ACE.

The DCSA was measured three times on each image, and the mean value was calculated. A statistically significant decrease in DCSA from PRP to ACE had occurred if the decrease exceeded 15 mm².³ The presence of disc degeneration, protrusion, or herniation was recorded. Facet joint arthrosis, recess, and foraminal narrowing were determined as well as deformation of the dural sac from PRP to ACE.

■ Results

Analysis of the Individuals Examined in Psoas-Relaxed Position and Axial Compression in Extension

In 43 individuals, 129 disc levels were examined. Disc degeneration was found at 56 levels (43%) in 31 individuals (72%). Disc protrusion was found at 19 levels (15%) in 11 subjects (26%). The frequency of disc degeneration and disc protrusion increased with age. Disc herniation was found at one level in a 27-year-old man with a lateral recess narrowing at the same level. A 46-year-old woman had a DCSA of 70 mm² on a level with recess narrowing. Facet arthrosis was recorded at five levels in five subjects older than 45 years. Foraminal narrowing was not found.

A significant decrease in DCSA (>15 mm² from PRP to ACE) was found at 35 disc levels (27%) in 24 individuals (56%) (Table 2). The mean decrease in DCSA was 25 mm² (range, 15–62mm²). In seven subjects, a significant decrease in DCSA was found at more than one disc level (Table 3).

A significant decrease in DCSA between PRP and ACE was most commonly found at L4–L5, and the frequency increased with age (Table 2). There was no difference between women and men. The DCSA values during PRP and ACE at each investigated disc level are shown in Figure 2.

The dural sac was deformed during ACE in six individuals, four of whom were older than 50 years. During



Figure 1. Axial compression of the lumbar spine with the DynaWell, a nonmagnetic device comprising a harness and a foot-operated compression device connected by straps. When the straps are tightened, an axial load on the spine is applied.

Table 2. Significant Decrease in Dural Cross-Sectional Area Between Examinations During Psoas-Relaxed Position and Axial Compression in Extension: Individuals and Disc Levels in Different Age Groups

	Age (years)				Σ
	20–29	30–39	40–49	50–59	
Individuals	5	4	8	7	24
Disc level					
L3–L4	5	—	4	2	11
L4–L5	3	4	6	6	19
L5–S1	2	—	1	2	5
Σ	10	4	11	10	35

Σ = 24/43 (56%) individuals; 35/129 (27%) levels.

Table 3. Individuals in Different Age Groups Eliciting a Significant Decrease in Dural Cross-Sectional Area Between Examination in Psoas-Relaxed Position and Axial Compression in Extension on More Than One Disc Level

Disc Level	Age (years)				Σ
	20–29	30–39	40–49	50–59	
L3–L5	1	—	1	2	4
L3–S1	2	—	1	—	3

Σ = 7 individuals.

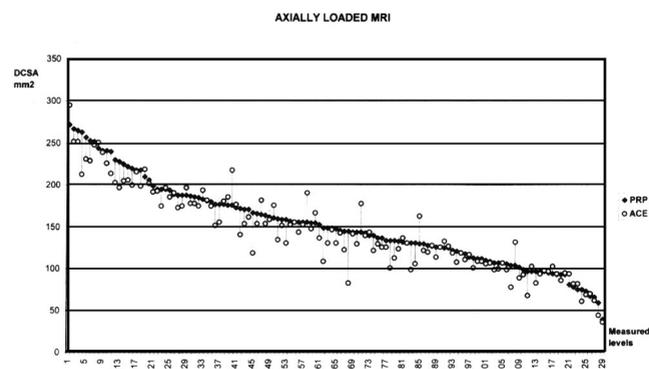


Figure 2. Graphic illustration of the dural sac cross-sectional area (DCSA) changes between MRI examination in psoas-relaxed position (filled squares) and in axial compression in extension (open circles) at each disc level evaluated.

Table 5. Dural Cross-Sectional Area Smaller Than 75 mm² During Axial Compression in Extension: Individuals and Disc Levels in Different Age Groups

	Age (years)				Σ
	20–29	30–39	40–49	50–59	
Individuals	2	1	3	1	7
Disc level					
L3–L4	—	—	—	—	—
L4–L5	—	—	1	1	2
L5–S1	2	1	2	—	5

Σ = 7/129 (5%) levels; 7/43 (16%) individuals.

PRP, the DCSA was smaller than 100 mm² at (16%) levels 20 in 16 subjects (37%). A significant decrease in DCSA was noted in two cases. During ACE the DCSA was smaller than 100 mm² at 24 levels (19%) in 16 subjects (37%) (Table 4), and less than 75 mm² at 7 levels (5%) in 7 individuals (16%) (Table 5). A significant decrease in DCSA (<100 mm²) from PRP to ACE was found at five levels in four subjects, all at L4–L5 (Table 6).

Analysis of the Individuals Who Were Reexamined

In the seven individuals who were reexamined, 14 disc levels, L3 to L5, were evaluated. Six of the seven subjects had disc degeneration at both levels, and two had disc protrusion at both levels. One subject had facet joint arthrosis, and none of the subjects had disc herniation.

A significant decrease in DCSA was found in all individuals at L4–L5, but only in five subjects at L3–L4. After 5 minutes of ACE, a significant decrease in DCSA at one or two disc levels was found in five individuals: in three individuals after a load of 25% of their body weight, and in two individuals after a load of 50% of their body weight. In two subjects, a decrease in DCSA was found after a load of 50% of their body weight for 20 and 40 minutes, respectively.

Discussion

Pathologic conditions such as disc degeneration, protrusion, herniation, and spinal stenosis in the lumbar spine

Table 4. Dural Cross-Sectional Area Smaller Than 100 mm² in (a) Psoas-Relaxed Position (PRP) and (b) Axial Compression in Extension (ACE): Individuals and Different Disc Levels in Different Age Groups

	Age (years)								Σ	
	20–29		30–39		40–49		50–59		a	b
	a	b	a	b	a	b	a	b		
Individuals	4	4	4	3	5	6	3	3	16	16
Disc level										
L3–L4	1	1	—	1	1	1	1	1	3	4
L4–L5	1	3	—	—	1	1	1	3	3	7
L5–S1	4	3	4	3	4	5	2	2	14	13

Σ = PRP: 20/129 (16%) levels; ACE: 24/129 (19%) levels; PRP and ACE: 16/43 (37%) individuals.

Table 6. Individuals With a Dural Cross-Sectional Area (DCSA) Significantly Decreasing ($> 15 \text{ mm}^2$) to Less Than 100 mm^2 from (a) Psoas-Relaxed Position to (b) Axial Compression in Extension (ACE):

Age (years)	L4–L5			L5–S1		
	a	b	a–b	a	b	a–b
♀ 25	131	99	–32	59	44	–15
♂ 27	104	78	–26			
♀ 52	145	83	–62			
♂ 58	97	68	–29			

$\Sigma = 4$ individuals; 5 disc levels.

of asymptomatic and symptomatic individuals examined by CT scan and MRI have been compared in several studies^{1,4,6,7,11,16,17,19}. Recently, it has been shown that in patients with clinical symptoms of lumbar spine encroachment, axial loading during CT scan and MRI induces a significant decrease in DCSA.^{3,18,21} Therefore, it was necessary to evaluate the effect of axial loading on the DCSA in asymptomatic individuals, as compared with the effect in patients who have lumbar spine disorders such as low back pain, sciatica, and neurogenic claudication.

Evaluation of the images was performed as described in two recently published studies.^{3,21} This procedure implies careful selection of transverse images to be calculated and compared, performance of three DCSA measurements on every image, and selection of at least a 15-mm^2 difference in DCSA to be regarded as a true difference between measurements, in accordance with the measurement error study published earlier.³

Degenerative disc changes commonly are found in asymptomatic subjects, and increasingly with age.^{6,7,17,20,22} Salo et al¹² investigated the prevalence of disc degeneration in pediatric patients with spine disease and also in control subjects younger than 15 years. They found disc degeneration in 13% and 22% of those individuals, respectively. Boden et al¹ performed MRI on 67 asymptomatic individuals. They found a disc degeneration or protrusion in 35% of the subjects between 20 and 39 years of age, and in all but one of those 60 to 80 years old. Narrowing of the spinal canal was found in 21% of those older than 60 years.

Greenberg and Schnell⁵ performed MRI of the lumbar spine in 66 asymptomatic individuals and reported disc protrusion or herniation in 18% of these subjects. A disc bulge found in another 39% of the individuals was associated with degenerative disc disease. Healy et al⁶ evaluated the lumbar spine in asymptomatic active male athletes with a mean age of 53 years. They found spinal canal narrowing in 15% of the subjects. Jensen et al⁷ performed lumbar spine MRI in 100 asymptomatic individuals ages 20 to 75 years and found spinal canal narrowing in 15% of the subjects.

The current findings of disc degeneration in 72%, protrusion in 26%, and spinal canal narrowing in 16% of

the individuals as well as disc herniation in one young person are consistent with what has been described earlier concerning degenerative spine diseases in individuals at different ages.

Danielson et al³ and Willén et al²¹ evaluated patients with clinically suspected lumbar spinal canal encroachment. During MRI, a significant decrease in DCSA from PRP to ACE was described at 37 of 81 disc levels (46%) and in 26 of 34 patients (76%). The mean decrease in DCSA was reported to be 27 mm^2 at L3–L4, 30 mm^2 (range, $15\text{--}43 \text{ mm}^2$) at L4–L5, and 30 mm^2 (range, $15\text{--}46 \text{ mm}^2$) at L5–S1. In 8 of 34 patients (24%), the DCSA changed from greater than 100 or 75 mm^2 during PRP to less than 100 or 75 mm^2 during ACE.

Talloth et al¹⁸ reported on 100 patients (mean age, 48 years) with chronic low back problems including symptoms suggesting spinal stenosis. A conventional CT scan of the lumbar spine was performed from L3 to S1, followed by an examination in compression, using the DynaWell. A decrease in DCSA was found in almost every patient. A stenosis (DCSA $< 75 \text{ mm}^2$) was found at 59 (20%) and 86 (29%) of 300 disc levels before and after compression, respectively. They concluded that the diagnosis of central spinal stenosis was clarified by the compression examination.

In the current study, comparison of DCSA during PRP and ACE showed a significant decrease at 35 disc levels (27%) in 24 individuals (56%). The mean decrease in DCSA was 25 mm^2 (range, $15\text{--}62 \text{ mm}^2$).

In a study on cadavers, Schönström and Hansson¹⁴ found a dural sac pressure increase in a cross-sectional area of $77 \pm 13 \text{ mm}^2$. In clinical practice, a DCSA smaller than 100 and 75 mm^2 , respectively, often is classified as a relative or absolute central spinal stenosis.

In the current study, a DCSA smaller than 100 mm^2 was found in 16 subjects during PRP, predominantly at L5–S1. A significant DCSA decrease was found during ACE in only two of these subjects (Table 6). In axial compression, the DCSA was smaller than 100 mm^2 in 16 individuals, but all were not identical. A significant decrease from the unloaded position had occurred in 4 subjects (9%) at five disc levels (Table 6). The DCSA changed significantly in only 3 subjects (7%) from more than to less than 100 mm^2 during ACE, none below 75 mm^2 .

In a comparison of results from the studies on patients and asymptomatic individuals after MRI in PRP and ACE, a substantial difference in effect of axial loading on the dural cross-sectional area in these two groups was demonstrated. A decrease in DCSA between PRP and ACE was found to be more frequent among patients (76%) than among asymptomatic subjects (56%). A decrease in DCSA from more than to less than 100 mm^2 was found in 24% of the patients and in 9% of the asymptomatic individuals (Table 7). These findings support the recommendation that MRI examination of the lumbar spine should be performed in the axially loaded

Table 7. Disc Protrusion, Disc Herniation, and Decrease in Dural Cross-Sectional Area (DCSA)- From Psoas-Relaxed Position (PRP) to Axial Compression in Extension (ACE) in Asymptomatic and Symptomatic Individuals³

	Asymptomatic		Symptomatic	
	Levels (n = 129) n	Individuals (n = 43) n (%)	Levels (n = 81) n	Individuals (n = 34) n (%)
Disc protrusion	21	16 (37)	51	
Disc herniation	1	1	10	10
Decrease in DCSA in ACE	27	24 (56)	37	26 (76)
Decrease in DCSA from PRP to ACE to less than 100 mm ²		4 (9)		8 (24)

position in patients with clinical symptoms of neurogenic claudication, sciatica, or both.

Schönström et al¹⁵ proposed that in asymptomatic individuals, a DCSA smaller than 75 mm² in the lumbar spine should be regarded as a narrow canal and not a spinal stenosis. In the current study, some individuals with a DCSA smaller than the critical value during PRP showed a further decrease during ACE and experienced a development of borderline DCSA at other disc levels. Despite this, they were asymptomatic (Figure 3).

In evaluating patients with symptoms of lumbar spinal canal encroachment it is essential to correlate the findings from the MRI examination with clinical signs and symptoms, and to report not only measurements, but also the general impression of the dural sac or nerve root entrapment. In the authors' opinion, it is essential to compare images during PRP and ACE at the same disc level when evaluating dural sac or nerve root compression.

As a recommendation for daily management of MRI examination procedures during ACE, the impact of axial load magnitude and duration and its effect on the dural sac should be evaluated. Seven of the asymptomatic subjects previously studied were reexamined. Individuals in age groups and disc levels were selected for whom a decrease in DCSA was most common. Subjects from 40 to 60 years of age and disc levels from L3 to L5 were chosen for this evaluation. Axial sequences were conducted with axial load durations of 5 to 60 minutes because this was the maximum time the individuals could tolerate the load.

The reexamination of seven individuals evoked a significant DCSA decrease in five of the individuals within 5 minutes of axial loading. A DCSA decrease was found in two more individuals after extended loading time. Therefore, as a routine, a loading time of 5 minutes is considered sufficient.

While 50% of their body weight was being loaded, all seven individuals showed a decrease in DCSA, as com-

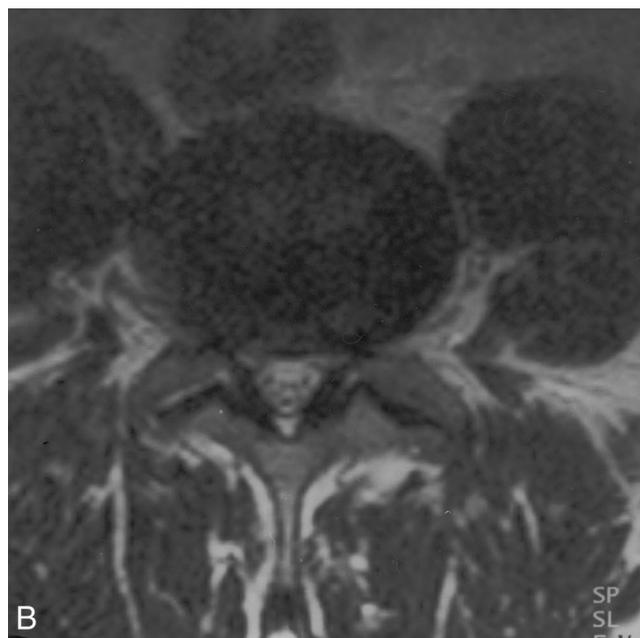
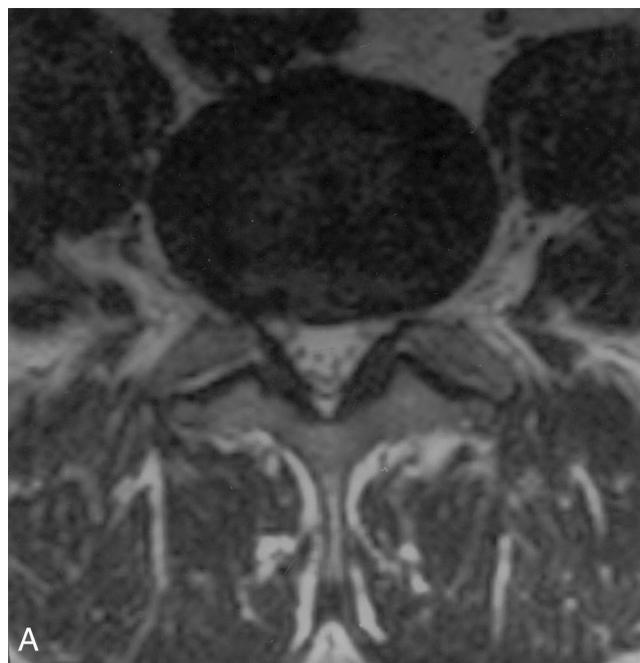


Figure 3. Asymptomatic 58-year-old man. T2-weighted image of L4–L5 during PRP. **A**, axial compression in extension (ACE). **B**, The dural sac cross-sectional area was 97 mm² in psoas-relaxed position (PRP) and 68 mm² in ACE. An accentuated compression on the nerve root in the right recess was found. At L5–S1, the DCSA was 95 mm² during PRP, and 97 mm² during ACE (not shown). No symptoms occurred during axial loading.

pared with three individuals after 25% loading. Therefore, the authors believe that every effort should be made to apply the higher load when axially loaded MRI examination of the lumbar spine is performed.

■ Conclusion

In asymptomatic individuals, MRI examination of the lumbar spine in psoas-relaxed position (PRP) and in ax-

ial loading (ACE) resulted in less frequent reduction of the dural cross sectional area (DCSA) between positions than in patients with clinical signs of neurogenic claudication and sciatica. The DCSA decrease in asymptomatic individuals was most frequent at L4–L5 level, and it was found that frequency increased with age. A DCSA smaller than the critical value of 100 mm² was found, but a decrease between PRP and ACE was unusual and not accompanied by any symptoms.

The findings highly support the recommendation that MRI examination of the lumbar spine should be performed in both PRP and ACE for patients with clinically suspected lumbar spinal canal encroachment. It is most important to register the general impression concerning compression of the dural sac and nerve roots. This is facilitated by comparing images in different positions. The applied load should be 50% of the subject's body weight, and the load should be maintained for at least 5 minutes before the CT or MRI examination.

■ Key Points

- In asymptomatic individuals, MRI examination of the lumbar spine in psoas-relaxed position (PRP) and in axial loading (ACE) resulted less frequently in decreased dural cross-sectional area (DCSA) between positions (56%), as compared with the effect on patients who have clinical signs of neurogenic claudication and sciatica (76–80%).
- The findings highly support the recommendation that MRI examination of the lumbar spine be performed in both PRP and ACE for patients with clinically suspected lumbar spinal canal encroachment.
- The applied load should be 50% of the subject's body weight, and the load should be maintained for at least 5 minutes before the CT or MRI examination.

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