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Anatomical impairments and functional disability in patients with lumbar disc herniation

Повезаност структурних оштећења и функционалне онеспособљености код пацијената са лумбалном дискус хернијом

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Anatomical impairments and functional disability in patients with lumbar disc herniation

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SUMMARY

Introduction/Objective Magnetic resonance imaging (MRI) is a key diagnostic tool for low back pain (LBP), particularly when radiculopathy due to lumbar disc herniation is suspected. The objective of this study was to evaluate how MRI characteristics—herniation size, location, and nerve involvement—correlate with pain intensity and functional disability.

Methods The prospective study included 200 patients (mean age 59.7 ± 11.2 years; 51.8% female) with MRI-confirmed lumbar disc herniation and LBP. Prospective patient enrollment and clinical assessment were conducted between April 2011 and January 2012, while the verification of baseline medical records pertained to the cohort from October 2010. Pain was assessed using the Visual Analogue Scale (VAS), Pain DETECT questionnaire, and Oswestry Disability Index (ODI v2.1). Spinal mobility was measured using the Schober and Thomayer tests. MRI was used to analyze herniation size (≤ 3 mm / > 3 mm), localization (central, dorsolateral, lateral), and the degree of nerve root compression (contact, dislocation, compression).

Results Median pain duration was 15.7 months; 46% of patients reported leg radiation. Herniation > 3 mm was found in 73.2% of participants. Pain radiation and ODI disability scores were significantly higher in patients with dorsolateral herniation and herniation > 3 mm ($p < 0.05$). Among patients with radiating pain, 69,7% showed MRI-visible nerve root or thecal sac compression, associated with the highest pain and disability scores ($p < 0.05$).

Conclusion While herniation size influences symptom severity, dorsolateral localization and nerve involvement are stronger determinants of pain and functional disability. MRI findings that demonstrate these changes are clinically valuable for diagnosis and treatment planning.

Keywords: lumbar disc herniation; MRI; radiculopathy; functional disability; low back pain

САЖЕТАК

Увод/Циљ Магнетна резонанца (*MRI*) је кључна дијагностичка метода код бола у доњем делу леђа (*LBP*), нарочито када се сумња на радикулопатију услед лумбалне дискус херније. Циљ студије био је да се испита повезаност између *MRI* карактеристика—величине и локализације херније и захваћености нервних структура—са интензитетом бола и функционалним инвалидитетом.

Методе У проспективну студију је укључено 200 пацијената (просечна старост 59.7 ± 11,2 година; 51,8% жена) са *MRI* потврђеном лумбалном дискус хернијом и *LBP*. Проспективно укључивање пацијената и клиничка процена спроведени су између априла 2011. и јануара 2012. године, док се верификација почетне медицинске документације односила на кохорту од октобра 2010. Бол је процењен помоћу *VAS* скале, *Pain Detect* теста и *Oswestry Disability Index* (*ODI v2.1*). Покретљивост кичме мерена је *Schober* и *Thomayer* тестом. *MRI* је анализирао величину херније (≤ 3 *mm* / > 3 *mm*), локализацију (централна, дорзолатерална, латерална) и степен компресије нерва (контакт, дислокација, компресија).

Резултати Средње трајање бола било је 15,7 месеци; 46% пацијената имало је зрачење бола у ногу. Хернија > 3 *mm* нађена је код 73,2% испитаника. Зрачење бола и *ODI* скор били су значајно виши код дорзолатералних хернија и хернија > 3 *mm* ($p < 0,05$). Код пацијената са радијацијом бола, 69,7% је имало *MRI* доказану компресију нервног корена или дуралне кесе, што је било повезано са највишим степеном бола и инвалидитета ($p < 0,05$).

Закључак Иако величина херније утиче на тежину симптома, дорзолатерална локализација и компресија нерва су јачи предиктори бола и функционалног оштећења.

Кључне речи: лумбална дискус хернија; магнетна резонанца; радикулопатија; функционална онеспособљеност; бол у доњем делу леђа

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INTRODUCTION

Low back pain (LBP) is one of the most prevalent health problems worldwide and a leading cause of disability, work absenteeism, and reduced quality of life [1, 2, 3]. The lifetime prevalence of LBP exceeds 80%, and approximately 10–20% of affected individuals develop chronic symptoms requiring prolonged treatment and rehabilitation [4, 5].

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Lumbar disc herniation (LDH) is among the most frequent structural causes of LBP and radiculopathy [6, 7]. It occurs when nucleus pulposus material protrudes or extrudes through the annulus fibrosus, compressing adjacent neural structures, most commonly the spinal nerve roots [8, 9]. The clinical manifestation depends on the size, location, and degree of nerve root involvement, as well as individual biomechanical and psychosocial factors [10]. Magnetic resonance imaging (MRI) remains the gold standard for evaluating LDH due to its excellent soft tissue contrast and ability to visualize intervertebral discs, nerve roots, and thecal sac compression [11, 12].

MRI findings are frequently used to confirm clinical suspicion and guide therapeutic decisions, particularly when surgical intervention is being considered [13–15]. However, numerous studies have emphasized that radiological abnormalities are common even among asymptomatic individuals and do not always correlate with pain intensity or functional impairment [16, 17]. This discrepancy underscores the complexity of LBP as a multifactorial condition that cannot be fully explained by structural pathology alone. The biopsychosocial model of pain proposes that physical, psychological, and social determinants jointly contribute to symptom perception and chronicity [18, 19]. Nevertheless, in clinical practice, precise identification of MRI features that are most strongly associated with clinically significant pain and disability remains crucial for accurate diagnosis and rational treatment planning [20, 21, 22].

The present study aimed to analyze the relationship between MRI characteristics of lumbar disc herniation, including size, localization, and degree of nerve involvement, and clinical manifestations, such as pain intensity, radiation, and functional disability. We hypothesized that dorsolateral herniation and MRI-visible nerve compression would correlate most strongly with radicular pain and reduced spinal mobility.

METHODS

Study design and participants

This was a prospective observational study conducted at the Clinic for Medical Rehabilitation, Clinical Center of Vojvodina, Novi Sad, Serbia. The study protocol was approved by the Ethics Committee of the Clinical Center of Vojvodina and conducted in accordance with the Declaration of Helsinki (2008 revision). A total of 200 adult patients diagnosed with lumbar disc herniation and low back pain (LBP) were included (104 females – 51.8%, 96 males – 48.2%). Prospective recruitment and clinical evaluations under the approved study protocol were conducted between April 2011 and January 2012, while baseline medical record verification applied to the initial cohort from October 2010. Inclusion criteria were: MRI-confirmed lumbar disc herniation, presence of low back pain with or without leg radiation, and age between 20 and 74 years. Exclusion criteria included diabetes mellitus, chronic alcoholism, previous lumbar spine surgery, inflammatory or neoplastic spinal disease, and inability to complete questionnaires due to cognitive or language barriers. All participants provided written informed consent prior to inclusion.

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Magnetic resonance imaging (MRI) assessment

MRI examinations were performed using a 1.5 Tesla scanner with sagittal T1-weighted, sagittal T2-weighted, and axial T2-weighted sequences of the lumbosacral spine. MRI findings were interpreted by a board-certified radiologist with two years of post-certification experience who was blinded to the clinical data. The following parameters were evaluated: 1) disc herniation level: L2-L3, L3-L4, L4-L5, L5-S1; 2) location: central, dorsolateral, or lateral; 3) herniation size was measured in millimeters on sagittal MRI images as the maximum anteroposterior distance from the posterior margin of the vertebral body or annulus fibrosus to the most posterior point of the herniated disc material. Measurements were categorized as ≤ 3 mm or > 3 mm; 4) nerve root involvement: graded according to Pfirrmann et al. [11] as no contact, contact, displacement, or compression; 5) thecal sac compression: presence or absence.

Clinical evaluation

Clinical evaluation included pain assessment, disability measurement, and functional mobility testing.

Pain intensity

Assessed by the visual analogue scale (VAS) ranging from 0 (no pain) to 10 (worst imaginable pain).

Two ratings were recorded: current pain and maximum pain in the previous four weeks.

Pain quality and radiation

Evaluated using the pain detect questionnaire (PDT)

Radiation patterns were recorded as buttock, below buttock, or absent.

Functional disability

Measured using the Oswestry Disability Index (ODI v2.1), which assesses the impact of pain on daily activities, mobility, and work capacity [23].

Spinal mobility

Schober Test: measures lumbar flexion in centimeters.

Thomayer Test: measures fingertip-to-floor distance during forward flexion.

Additionally, male participants were asked to self-assess their physical work ability and the degree of its reduction during the last four weeks, grouped as: < 20%, 20–39%, 40–59%, 60–80%, > 80%, or unable to work.

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Data collection and statistical analysis

Demographic and clinical data, test results, and MRI findings were entered into a standardized database. Statistical analysis was performed using STATA version 11. Continuous variables were presented as mean ± standard deviation (SD) or median (range), depending on data distribution. Comparisons between groups were conducted using Student's t-test for normally distributed data and Mann–Whitney U test for non-parametric data. Associations between MRI findings, pain characteristics, and functional parameters were evaluated using Pearson's correlation coefficient and Poisson regression to estimate prevalence ratios (PR) with 95% confidence intervals (CI). A p-value < 0.05 was considered statistically significant.

RESULTS

Demographics and MRI findings

A total of 200 patients were included in the study (104 females, 51.8%; 96 males, 48,2%). The mean age was 59.7 ± 11.2 years (range: 28–74 years). Most participants were between 50 and 74 years of age (47%). Baseline demographic data are presented in Table 1.

Pain duration varied considerably among patients, ranging from less than two months to more than two years. The median duration was 15.7 months, and 46% of patients reported leg pain radiation. Distribution of pain duration and radiation sites is shown in Table 2.

Patients with pain radiating below the buttock reported significantly higher pain intensity (VAS) and higher ODI disability scores compared to those without radiation ($p < 0.05$). MRI findings revealed that 146 patients (73.2%) had herniation larger than 3 mm. Most herniation was found at the L4–L5 (47%) and L5–S1 (33%) levels. Detailed results are presented in Tables 3–5. Pain radiation was significantly more common among patients with herniation larger than 3 mm ($p < 0.05$). The L4–L5 and L5–S1 levels were the most frequently affected, while extrusion was the predominant herniation type.

MRI-visible nerve root involvement or thecal sac compression was present in 69.7% of patients with pain radiation (n = 92). The distribution is presented in Table 6.

Patients with visible nerve root compression demonstrated significantly higher pain (VAS, PDT) and disability (ODI) scores compared to those without impingement ($p < 0.05$).

Functional tests and pain scores

All participants completed standardized pain and disability assessments. Mean scores indicated moderate-to-severe pain and notable functional limitation (Table 7). Pain intensity (VAS) correlated strongly with both ODI ($r = 0.75$, $p < 0.001$) and PDT ($r = 0.70$, $p < 0.001$).

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Effect of herniation size and location

Patients with herniations > 3 mm had significantly higher pain and disability scores ($p < 0.05$) (Table 8). Dorsolateral herniations were linked to the highest pain and disability (Table 9).

Impact of nerve root impingement

Progressive nerve involvement was associated with increasing pain and disability (Table 10).

Physical work ability in men

Among male participants (n = 96), those with larger herniation (> 3 mm) or dorsolateral localization reported marked declines in work ability (Tables 11 and 12).

To sum up:

MRI-visible nerve involvement was found in 69.7% of patients with leg radiation.

Herniation > 3 mm and dorsolateral location were both significantly associated with higher VAS, PDT, and ODI scores ($p < 0.05$).

Compression severity showed a stepwise increase in pain and disability scores ($p < 0.001$).

Schober and Thomayer tests correlated inversely with both herniation size and nerve compression ($r = –0.65$ and $r = –0.61$, respectively).

DISCUSSION

This prospective study demonstrated that the size, localization, and MRI-visible nerve involvement of lumbar disc herniation are all significantly associated with pain intensity, radiation, and functional disability. In particular, dorsolateral herniation and herniation larger than 3 mm were most strongly correlated with radicular pain, higher Oswestry Disability Index (ODI) scores, and reduced spinal mobility. These results are in agreement with previous studies showing that MRI findings of nerve root contact or compression correlate with clinical symptoms in a majority of patients [11, 12, 13, 20, 21]. Furthermore, recent anatomical evaluations confirm that morphometric vertebral changes, particularly at the L4–L5 level, closely correspond with the clinical stages of disc herniation [2]. However, our findings also confirm that the relationship between structural abnormalities and symptom severity is not absolute, reinforcing the multifactorial nature of low back pain [6, 16–18].

The dorsolateral and foraminal regions of the intervertebral disc are anatomically the most critical because of their close proximity to the exiting spinal nerve root and dorsal root ganglion. Even minor protrusions in these zones can cause pronounced radicular pain [12, 13]. In contrast, centrally located herniation often compresses the thecal sac without producing severe neurological symptoms. Our results confirm that the spatial relationship between the herniated disc and the neural structures, rather than

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absolute herniation size, determines clinical relevance. This is consistent with the grading approach proposed by Pfirrmann et al. [11] emphasize localization and nerve contact as key predictors of symptom severity.

The pattern of findings aligns with modern imaging literature, including recent WFNS Spine Committee recommendations and Korean Neurospine 2025 guidelines, which confirm that MRI-visible nerve root involvement remains the strongest radiologic correlate of radiculopathy [19, 20, 21]. Similarly, the 2025 systematic review of lumbar disc herniation guidelines [22] and Dragsbæk et al. [23, 24] concluded that combinations of multiple MRI abnormalities, such as protrusion plus foraminal stenosis, better predict symptom burden than any single lesion. Our results also support the biopsychosocial model of pain, emphasizing that psychological and occupational factors modulate pain perception [17, 18]. Although MRI can confirm anatomic compression, individual differences in coping, stress, and work demands strongly influence functional outcomes

Recent consensus statements, including the ACR Appropriateness Criteria and NICE guideline NG59, advise against routine imaging in all LBP patients [16, 17]. MRI should be reserved for cases with red-flag symptoms or suspected radiculopathy that may change management. Our data reinforce this approach: in patients with clinically evident radiation, MRI added clear diagnostic value, but in others, findings were nonspecific. Therefore, MRI should be viewed as a confirmatory rather than a screening tool, interpreted alongside clinical and functional assessments. This approach aligns with 2024–2025 global guideline updates that integrate imaging with patient-reported outcomes and psychosocial risk stratification [21, 22, 23, 25]

Reduced Schober and Thomayer scores among patients with nerve compression confirm that structural pathology translates into measurable limitations in spinal mobility.

Furthermore, the observed decline in physical work ability, particularly among men with large or dorsolateral herniation, highlights the socioeconomic impact of symptomatic disc disease. Similar trends were reported in occupational studies [15, 19], underscoring the importance of early rehabilitation and ergonomic adaptation in returning patients to work.

The strengths of this study include a prospective design, homogeneous population, and standardized MRI evaluation performed by a blinded radiologist. The use of both subjective (VAS, PDT, ODI) and objective (Schober, Thomayer) measures strengthens the validity of observed correlations. However, the study has limitations. It was conducted in a single tertiary center, with a moderate sample size and without long-term follow-up. Thus, the predictive value of MRI findings for chronic pain persistence could not be established. Future longitudinal studies incorporating quantitative MRI metrics (nerve root displacement volume, spinal canal cross-sectional area) are needed to refine prognostic accuracy. Future research should combine radiologic, clinical, and psychosocial parameters into integrated predictive models that can guide individualized treatment decisions. Advanced MRI techniques, such as diffusion tensor imaging and quantitative T2 mapping, may provide better insight into neural inflammation and

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early degeneration. Moreover, the integration of AI-based radiomics and automated segmentation could enhance diagnostic precision and standardize the interpretation of spine imaging in both research and clinical practice [22, 23].

CONCLUSION

In this prospective clinical study, we confirmed that both the localization and the degree of MRI-visible neural involvement are stronger predictors of pain and functional disability than herniation size alone. Patients with dorsolateral herniation and nerve root or thecal sac compression demonstrated the most severe symptoms, highest ODI scores, and greatest reductions in spinal flexibility and work ability. Although MRI remains indispensable for anatomical assessment, imaging findings should always be interpreted in the context of clinical presentation and psychosocial factors influencing pain and recovery. Understanding these correlations supports a more precise and personalized approach to rehabilitation and clinical decision-making in patients with lumbar disc herniation.

Ethics: The study protocol was approved by the Ethics Committee of the Clinical Center of Vojvodina (No. 00-01/171, April 5, 2011).

Conflict of interest: None declared.

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Table 1. Demographic characteristics of the study population, including age distribution and sex structure (n = 200)

Variable	Median or %
Age (years, range)	59.7 (28–74)
20–39 years	22.4%
40–49 years	30.6%
50–74 years	47%
Sex	
Female	51.8%
Male	48.2%

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Table 2. Duration of pain and the frequency and distribution of pain radiation among the participants

Parameter	n (%)
Duration < 2 months	38 (19%)
Duration 2–12 months	48 (24%)
Duration 1–2 years	28 (14%)
Duration > 2 years	86 (43%)
Mean pain duration (months)	15.7
Pain radiation present	92 (46%)
Into buttock	41 (20.5%)
Below buttock	51 (25.5%)

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Table 3. Distribution of patients according to the size of lumbar disc herniation identified on MRI

Herniation size	n (%)
≤ 3 mm	54 (26.8%)
> 3 mm	146 (73.2%)

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Table 4. Relationship between pain radiation and the size of disc herniation (n = 92)

Pain radiation	Herniation > 3 mm	Herniation ≤ 3 mm	p-value
Into buttock (n = 41)	34 (83%)	7 (17%)	< 0.05
Below knee (n = 51)	46 (90%)	5 (10%)	< 0.05

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Table 5. Anatomical level and morphological type of disc herniations larger than 3 mm (n = 146)

Parameter	n (%)
Level of herniation	
L2–L3	6 (6%)
L3–L4	18 (18%)
L4–L5	45 (44%)
L5–S1	32 (32%)
Two or more levels	45 (44%)
Type of herniation	
Protruding	27 (27%)
Extruded	67 (66%)
Sequestered	7 (7%)

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Table 6. Frequency of nerve root and thecal sac involvement detected by MRI in patients with radiating pain (n = 92)

Impingement type	n (%)
No impingement	28 (30.3)
Any visible impingement	64 (69.7)
Nerve touching	10
Nerve deviation	20
Nerve compression	24
Thecal sac compression	10

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Table 7. Results of pain intensity, disability, and spinal mobility assessments (n = 200)

Test	Range (min–max)	Mean ± SD
Pain detect score	11–46	23.1 ± 10.2
VAS (current)	2–9	6.7 ± 2.1
VAS (worst, 4 weeks)	2–9	6.8 ± 2.1
Oswestry Disability Score	12–68	35.5 ± 14.5
Thomayer test (cm)	10.5–44.4	22 ± 8.7
Schober test (cm)	1.8–5.6	3.6 ± 0.9

VAS – visual analogue scale

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Table 8. Comparison of pain intensity, functional disability, and spinal mobility according to herniation size

Test	> 3 mm (n = 146)	≤ 3 mm (n = 54)	p-value
Pain detect score	26.3 ± 10.1	14.2 ± 3.8	< 0.001
VAS (current)	7.6 ± 1.4	4.3 ± 1.4	< 0.001
VAS (4 weeks)	7.7 ± 1.5	4.4 ± 1.5	< 0.001
ODI score	41.5 ± 11.2	19.3 ± 5.0	< 0.001
Thomayer (cm)	25.0 ± 8.1	13.8 ± 3.2	< 0.001
Schober (cm)	3.2 ± 0.7	4.5 ± 0.6	< 0.001

VAS – visual analogue scale; ODI – Oswestry Disability Index

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Table 9. Association between herniation location and measures of pain, disability, and spinal mobility

Test	Lateral (n = 42)	Dorsal (n = 67)	Dorsolateral (n = 91)	p-value
Pain detect score	14.2 ± 3.9	22.3 ± 8.7	27.8 ± 10.3	< 0.001
VAS (current)	4.3 ± 1.3	6.5 ± 1.8	7.9 ± 1.2	< 0.001
VAS (4 weeks)	4.4 ± 1.4	6.6 ± 1.8	8.0 ± 1.3	< 0.001
ODI score	19.1 ± 4.8	31.7 ± 11.9	45.8 ± 10.6	< 0.001
Thomayer (cm)	13.7 ± 3.1	21.3 ± 7.9	26.4 ± 8.0	< 0.001
Schober (cm)	4.6 ± 0.6	3.6 ± 0.8	3.1 ± 0.6	< 0.001

VAS – visual analogue scale; ODI – Oswestry Disability Index

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Table 10. Relationship between the degree of neural involvement and clinical measures of pain, disability, and mobility

Impingement Type	Pain detect score	ODI score	VAS (current)	VAS (4 weeks)	Thomayer	Schober	p
No impingement (n = 28)	13.7 ± 3.6	18.8 ± 4.5	4.2 ± 1.2	4.3 ± 1.3	13.6 ± 3.1	4.5 ± 0.6	—
Touching (n = 10)	21.7 ± 4.5	39.7 ± 7.3	7.6 ± 1.4	7.8 ± 1.8	21.2 ± 6.7	3.2 ± 0.7	< 0.05
Deviation (n = 20)	28.5 ± 11.2	41.2 ± 8.9	7.7 ± 1.3	7.9 ± 1.3	28.3 ± 8.2	3.0 ± 0.6	< 0.05
Compression (n = 24)	34.4 ± 10.3	42.2 ± 7.3	8.7 ± 1.5	8.9 ± 1.6	33.4 ± 8.9	2.7 ± 0.7	< 0.05
Thecal sac compression (n = 10)	32.1 ± 5.6	44.1 ± 4.2	8.4 ± 1.7	8.3 ± 1.4	23.2 ± 6.8	3.2 ± 0.4	< 0.05

VAS – visual analogue scale; ODI – Oswestry Disability Index

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Table 11. Impact of herniation size on the reduction of work ability among male participants (men n = 96)

Reduction of work ability [%]	> 3 mm (n = 70) [%]	≤ 3 mm (n = 26) [%]	p
< 20	3 (4.3)	7 (26.9)	< 0.05
20–39	16 (22.9)	13 (50.0)	< 0.05
40–59	20 (28.6)	6 (23.1)	n.s.
60–80	12 (17.1)	0 (0)	< 0.05
> 80	5 (7.1)	0 (0)	< 0.05
Unable to work	14 (20)	0 (0)	< 0.001

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Table 12. Association between herniation location and the degree of work-ability reduction among male participants (men n = 96)

Location	< 20% [%]	20–39% [%]	40–59% [%]	60–80% [%]	> 80% [%]	Unable to work [%]
Lateral (n = 22)	27.3	40.9	18.2	13.6	0	0
Dorsal (n = 33)	12.1	24.2	24.2	21.2	3	15.2
Dorsolateral (n = 41)	4.9	9.8	29.3	24.4	9.8	21.8

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