Agri 2023;35(4):205–211
doi: 10.14744/agri.2022.42744

ORIGINAL ARTICLE

# The effect of lumbar multifidus cross-sectional areas on transforaminal epidural steroid injection: An observational clinical study

*Lomber multifidus kesit alanının transforaminal epidural steroid enjeksiyonu üzerine etkisi: Gözlemsel klinik çalışma*

**Rekib SAÇAKLIDIR,[1] Efe SOYDEMİR,[2] Savaş ŞENCAN,[1] Osman Hakan GÜNDÜZ[1]**

**Summary**

**Objectives:** Multifidus has an important role in spinal stability, and multifidus degeneration causes long-term disability and low back pain. This study aimed to investigate the effect of multifidus cross-sectional area on transforaminal epidural steroid injections (TFESI).

**Methods:** Patients with single-level disc herniation were included in the study. Total multifidus cross-sectional area (TM-CSA) and functional cross-sectional area (FM-CSA) were measured from axial T2 MRI of the patients, and FM-CSA/TM-CSA ratio was calculated for determination of muscle degeneration or fat infiltration. Numerical Rating Scale (NRS) scores at the pre-injection, 3rd week, and 3rd month visits were recorded. A decrease of 50% or more in the NRS score in the 3rd month was accepted as a treatment success (TS), and patients were divided into TS and treatment failure groups.

**Results:** A total of 120 patients were included in the study; 57 of the patients were female, and 63 of them were male. Of the patients included in the study, 68 had herniation at the L5-S1 disc level and 52 had herniation at the L4-L5 disc level. FM-CSA and FM-CSA/TM-CSA ratio were found to be significantly lower below the disc herniation level on the affected side ($p<0.05$). The affected side TM-CSA and FM-CSA were higher in the TS group and TM-CSA/FM-CSA ratios were equal in both groups.

**Conclusion:** Multifidus CSA was found to be lower on the affected side. However, the effect of multifidus CSA on the success of TFESI has not been determined.

Keywords: Epidural injections; lumbar disc herniation; multifidus; paraspinal muscle.

**Özet**

**Amaç:** Multifidus spinal stabilitede önemli bir role sahip olup multifidus dejenerasyonu uzun dönemde bel ağrısı ve engelliliğe neden olmaktadır. Bu çalışmada, multifidus kesit alanının transforaminal epidural steroid enjeksiyonu tedavisi üzerine olan etkisinin araştırılması amaçlandı.

**Gereç ve Yöntem:** Tek seviye disk hernisi olan hastalar çalışmaya dahil edildi. Hastaların aksiyel T2 manyetik rezonans görüntülerinden total multifidus kesit alanı ve fonksiyonel kesit alanı ölçüldü ve kas dejenerasyonu veya yağ dokusunun tespiti için fonksiyonel kesit alanı/total multifidus kesit alanı oranı hesaplandı. Enjeksiyon öncesi, üçüncü hafta ve üçüncü ay takiplerinde sayısal ağrı derecelendirme ölçeği skorları kaydedildi. Tedavi başarısı olarak üçüncü ayda sayısal ağrı derecelendirme ölçeği skorlarında %50 ve üzeri azalma kabul edildi ve hastalar tedavi başarısına ulaşanlar ve ulaşamayanlar olarak iki gruba ayrıldı.

**Bulgular:** Toplam 120 hasta çalışmaya dahil edildi; hastaların 57'si kadın, 63'ü erkekti. Çalışmaya dahil edilen hastaların 68'inde L5-S1 disk seviyesinde herniasyon, 52'sinde L4-L5 disk seviyesinde herniasyon mevcuttu. Fonksiyonel kesit alanı ve fonksiyonel kesit alanı/total multifidus kesit alanı oranı etkilenen tarafta disk hernisi seviyesinin altında anlamlı derecede düşük saptandı ($p<0,05$). Etkilenen tarafta total multifidus kesit alanı ve fonksiyonel kesit alanı tedavi başarısına ulaşan grupta daha yüksekti ve total multifidus kesit alanı/fonksiyonel kesit alanı oranlarında iki grup arasında fark saptanmadı.

**Sonuç:** Etkilenen tarafta multifidus kesit alanı daha düşük bulunmasına rağmen multifidus kesit alanının transforaminal epidural steroid enjeksiyonu tedavi başarısı üzerine etkisi saptanmamıştır.

Anahtar sözcükler: Lomber disk hernisi; epidural enjeksiyonlar; paraspinal kaslar; multifidus.

[1]Division of Pain Medicine, Department of Physical Medicine and Rehabilitation, Marmara University, Faculty of Medicine, İstanbul, Türkiye
[2]Department of Radiology, Marmara University, Faculty of Medicine, İstanbul, Türkiye

**Submitted** *(Başvuru)* **20.08.2022** **Revised** *(Revizyon)* **25.10.2022** **Accepted** *(Kabul)* **19.12.2022** **Available online** *(Online yayımlanma)* **18.10.2023**

**Correspondence:** Dr. Rekib Saçaklıdır. Marmara Üniversitesi, Pendik Eğitim ve Araştırma Hastanesi, Fiziksel Tıp ve Rehabilitasyon Anabilim Dalı, Ağrı Kliniği, İstanbul, Türkiye.
**Phone:** +90 - 216 - 625 45 45 **e-mail:** rakipsacakli@hotmail.com

## Introduction

Lumbosacral radiculopathy (LR) is defined as pain in the lower back and hip, which radiates to the lower extremity due to nerve compression. There are many causes of LR, including disc herniation, spinal stenosis, spondylolisthesis, osteophytes, foraminal stenosis, and degenerative diseases. However, the most common cause of LR is lumbar disc herniation (LDH), and the annual prevalence of LDH ranges from 2 to 34%.[1] Treatment options for LDH include conservative treatment, interventional pain procedures, and surgery.

Transforaminal epidural steroid injections (TFESI) are one of the preferred interventional pain procedures in patients unresponsive to conservative treatment. It is an effective treatment option in the short to medium term in selected cases that are clinically and radiologically evaluated.[2] In contrast, its long-term effectiveness is still controversial; for this reason, there is an ongoing need for better outcome predictors to select patients who would benefit most from TFESI.[3]

Lumbar paraspinal muscles are composed of multifidus and erector spina (iliocostalis, longissimus, and spinalis) muscles. The multifidus is located medially and has an important role in spinal stability.[4] Multifidus degeneration causes long-term disability and low back pain.[5] According to Park et al.,[6] fat infiltration and atrophy in the multifidus have been shown in patients with low back pain. These structural changes (atrophy, asymmetry, and fat infiltration) are thought to be precursors of low back pain and cause muscle dysfunction.[7]

Many studies have shown that the morphology of multifidus changes in patients with disc herniation, although as we know, the effect of these changes on TFESI has not been evaluated in patients with radiculopathy due to lumbar disc herniation.[8,9] Our aim in this study is to investigate the effect of a multifidus cross-sectional area on TFESI treatment success (TS).

## Material and Methods

After the approval of the ethics committee (Ethics number: 09.2020.1158), retrospectively, patients with lumbar disc herniation who applied to the pain medicine clinic were selected. Written informed consent forms were obtained from all patients. Patients who received TFESI with single-level disc herniation were included in the study. For the study, 745 patients who underwent lumbar TFESI between 2018 and 2019 were screened. A total of 120 patients with MR images and demographic and clinical follow-up data in the hospital system were included in the study (Fig. 1). Inclusion criteria were patients between the ages of 18–65, patients with nerve root compression due to a single level of disc herniation at the L4-5 or L5-S1 level, and patients whose MR images were recorded in the hospital data system. Exclusion criteria were previous lumbar surgery, spinal stenosis, scoliosis, transitional vertebra, spondylolysis-spondylolisthesis, coxofemoral pathology, and modic changes.

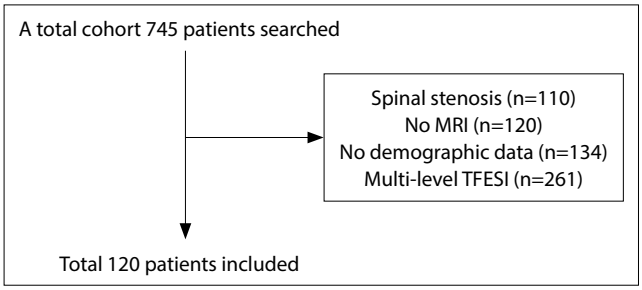


**Figure 1.** Participant flow diagram.

Demographic data of all patients, duration of symptoms, injection level, herniation level, and NRS pain scores at the pre-injection, 3rd week, and 3rd month controls were obtained from the records in the hospital system. A decrease of 50% or more in the NRS score at the 3rd month was accepted as a TS.[10]

## The Procedure

All procedures were performed under fluoroscopy by a pain medicine specialist (HG, SS) who has at least 10 years of experience. Patients were placed prone, and a pillow was placed under their abdomen to flatten the lumbar lordosis. The injection site was cleaned 3 times with batticon, and it was covered with a sterile drape. The fluoroscopy device was rotated oblique (10–30°) and cranial (0–15°) angles for visualization of the foramen. Local anesthetic (3 cc 2% prilocaine) was injected into the skin, subcutaneous tissue, and then the tip of a 22-gauge, 3.5-inch spinal needle was slowly advanced towards the 6 o'clock position of pedicle under intermittent fluoroscopic guidance. When the epidural space was approached, the lateral view confirmed whether the needle was in the subpedicular region. Then, 1–2 mL of contrast material was given. After the absence of vascularity was observed after epidural dissemina-

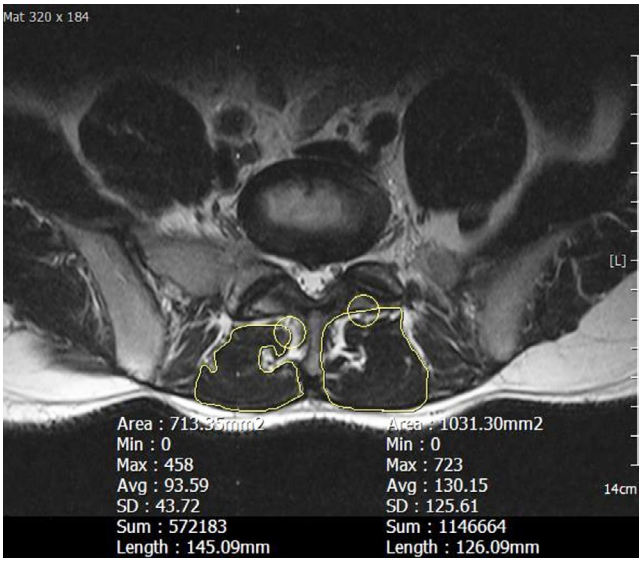


**Figure 2.** Functional (fat-free) cross-sectional area measurement was made based on the innermost fascia border to exclude adipose tissue (left side), and total multifidus cross-sectional area (TM-CSA) was defined based on the innermost fascial border to take the adipose tissue inside (right side).

**Table 1.** Baseline characteristics (n=120)

| Variable values | Mean (SD) or % |
|---|---|
| Age (years) | 37.93±15.6 |
| BMI (kg/m$^2$) | 26.89±3.52 |
| Symtom(months) | 9.48 (1–240) |
| PreNRS | 7.43±1.55 |
| Gender | |
| Male | 63 (52.5%) |
| Female | 57 (47.5%) |
| Herniation level | |
| L4-L5 | 52 (43.3%) |
| L5-S1 | 68 (56.7%) |
| MRI grade | |
| Grade 1–2 | 78 (67.2%) |
| Grade 3–4 | 38 (32.8%) |

Values are presented as mean±standard deviation; PreNRS: Preprocedure numeric rating scale; BMI: Body mass index.

tion, 3 cc of drug mixture (40 mg of triamcinolone, 1 cc of 0.5% bupivacaine, and 1 cc of saline) was injected. Patients were observed for possible complications 1 h after the injection.

## Radiological Evaluation

Lumbar MRIs of the patients were evaluated by an independent radiologist (ES) who was unaware of the patients' clinic and by an experienced pain medicine resident fellow (RS) in terms of MRI evaluation of the musculoskeletal system.

The classification system of Pfirmann et al.,[11] which shows the severity of nerve root compression with axial imaging, was used for the classification of disc herniation in lumbar MRI. In the classification of disc herniations, patients with grade 1 or 2 compression were classified as low and grade 3 or 4 as high-grade compression.

Total multifidus cross-sectional area (TM-CSA) and functional (fat-free) cross-sectional area (FM-CSA) were measured from axial T2 MR images of the patients, and FM-CSA/TM-CSA ratio was calculated bilaterally for determination of muscle degeneration or fat infiltration. TM-CSA was defined based on the innermost fascial border to take the adipose tissue inside. Fat between the multifidus and the lamina or spinous process is included in the TM CSA, while adipose tissue located between the multifidus and the erector spina muscle is not included. For FM-CSA, the measurement was made based on the innermost fascia border to exclude adipose tissue (Fig. 2).[12] Measurements were made separately for the right and left sides. For L5 and S1 root compression, the cross-sectional area was measured at the L4-5 and L5-S1 disc herniation levels, one level above and below disc herniation. All measurements were made from the midpoint of the disc level; only the below level measurement for L5-S1 herniation was made from the midpoint of the 1$^{st}$ sacral vertebra as in the previous study.[12]

## Statistical Analysis

Considering the relationship between the 6$^{th}$ month NRS score and multifidus CSA in the related study, the sample size was found to be 90 to achieve a 95% confidence interval and 80% power by G* Power 3.1 program (Version 3.1. 9.4).[13] In our study, all of the continuous variables (age, BMI, and NRS score) were found to be suitable for normal distribution using the Kolmogorov–Smirnov and Shapiro-Wilk tests. Chi-square and independent sample t-tests were used to compare the demographic data. An independent sample t test was used for comparison between groups. Intra-class correlation coefficients were used to determine the inter-rater reliability of the 18 MRI measurements between two readers and a value of <0.5 was poor, between 0.5 and 0.75 was moderate, between 0.75 and 0.90 was good, and >0.90 was considered excellent reliabil-

**Table 2.** Multifidus mean (standard deviation) muscle measurements in relation to the disc herniation on affected and unaffected sides, by herniation level (L4-L5, n=52; L5-S1, n=68) and both levels combined (n=120)

| | | | Side | | |
|---|---|---|---|---|---|
| | **Disc level** | **Herniation level** | **Affected** | **Unaffected** | **p** |
| Functional multifidus CSA ($cm^2$) | Above | L4-L5 | 5.5 (2.1) | 5.6 (2.2) | |
| | | L5-S1 | 7.0 (1.9) | 7.0 (1.9) | |
| | | Both | 6.4 (1.9) | 6.4 (1.9) | 0.855 |
| | Same | L4-L5 | 6.7 (2.0) | 7.2 (2.0) | |
| | | L5-S1 | 7.1 (1.6) | 7.5 (1.8) | |
| | | Both | 6.9 (1.9) | 7.4 (1.8) | 0.050 |
| | Below | L4-L5 | 6.9 (2.1) | 7.9 (2.0) | |
| | | L5-S1 | 6.9 (1.5) | 7.6 (1.6) | |
| | | Both | 6.9 (1.8) | 7.7 (1.9) | 0.009 |
| Total multifidus muscle CSA ($cm^2$) | Above | L4-L5 | 7.1 (2.5) | 7.2 (2.5) | |
| | | L5-S1 | 9.6 (1.7) | 9.6 (2.0) | |
| | | Both | 8.5 (2.5) | 8.6 (2.5) | 0.847 |
| | Same | L4-L5 | 9.5 (2.3) | 9.7 (2.4) | |
| | | L5-S1 | 11.4 (2.1) | 11.5 (2.0) | |
| | | Both | 10.6 (2.4) | 10.7(2.4) | 0.646 |
| | Below | L4-L5 | 11 (2.8) | 11.3 (2.3) | |
| | | L5-S1 | 10.7 (2.3) | 11.0 (1.9) | |
| | | Both | 10.9 (2.5) | 11.1 (2.1) | 0.356 |
| Ratio of functional multifidus CSA to total CSA | Above | L4-L5 | 0.78 (0.10) | 0.78 (0.09) | |
| | | L5-S1 | 0.74 (0.11) | 0.74 (0.11) | |
| | | Both | 0.76 (0.11) | 0.75 (0.10) | 0.838 |
| | Same | L4-L5 | 0.70 (0.09) | 0.74 (0.09) | |
| | | L5-S1 | 0.62 (0.10) | 0.65 (0.10) | |
| | | Both | 0.66 (0.10) | 0.69 (0.11) | 0.011 |
| | Below | L4-L5 | 0.70 (0.11) | 0.62 (0.11) | |
| | | L5-S1 | 0.64 (0.12) | 0.70 (0.11) | |
| | | Both | 0.63 (0.11) | 0.70 (0.10) | 0.001 |

Independent T test, values are presented as mean±standard deviation; CSA: Cross sectional area.

ity.[14] Statistical analysis was performed using SPSS version 20 (SPSS Inc., Chicago, IL, USA). P<0.05 was considered statistically significant.

## Results

A total of 120 patients with unilateral disc herniation in recess were included in the study; 57 of the patients were female, and 63 of them were male. The mean age of the patients was 38, and the mean duration of symptoms was 9.5 months. Of the patients included in the study, 68 had herniation at the L5-S1 disc level and 52 had herniation at the L4-L5 disc level (Table 1). In the multifidus CSA measurement, the inter-rater reliability of the 18 MRI measurements between two readers was excellent, with 0.94, 0.90 for right and left FM-CSA, and 0.98, 0.94 for TM-CSA, respectively.

In the present study, TM-CSA and FM-CSA at all levels were found to be lower on the affected side. However, statistically FM-CSA was found to be significantly lower below the disc herniation level on the affected side (p=009). FM-CSA/TM-CSA ratio was found to be statistically significantly lower at the level of herniation and below the herniation level on the affected side (Table 2).

**Table 3.** Comparison of demographics and affected multifidus-CSA between the two groups

| Variable values | Treatment success group (n=74) | Treatment failure group (n=46) | p |
|---|---|---|---|
| Age (years) | 37.08±17.1 | 39.39±12.5 | 0.436[a] |
| BMI (kg/m$^2$) | 26.8±3.6 | 26.9±3.4 | 0.975[a] |
| PreNRS | 7.3±1.6 | 7.5±1.4 | 0.907[a] |
| Symtom (months) | 10.18 (1–240) | 9.55 (1–48) | 0.446[a] |
| MRI grade | | | 0.450[b] |
| Grade 1–2 | 48 (45%) | 31 (25.8%) | |
| Grade 3–4 | 28 (23.3%) | 13 (10.8%) | |
| Affected TM-CSA(cm$^2$) | 1118.3±233.2 | 1029.2±275.9 | 0.062[a] |
| Affected FM-CSA(cm$^2$) | 698.0±197.0 | 673.5±138.9 | 0.470[a] |
| Affected TM-CSA/FM-CSA | 0.63±0.12 | 0.63±0.12 | 0.747[a] |

a: Independent T test; b: Chi-square test; BMI: Body mass index; PreNRS: Numeric rating scale preprocedure; TM-CSA: Total multifidus cross-sectional area; FM-CSA: Functional cross-sectional area; MRI: Magnetic resonance imaging.

The patients were divided into two groups according to the the 3rd month NRS score: TS and treatment failure (TF) groups. While the average NRS score before treatment was 7.3 in the TS group and 7.5 in the TF group, there was no significant difference between the groups. The duration of symptoms was 10 months in the TS group and 9.5 months in the TF group, and there was no significant difference between the two groups. No significant difference was found between age, BMI, and MRI grades (Table 3).

According to TS and affected side multifidus muscle characteristics in the 3rd month, although the affected TM-CSA and FM-CSA were higher in the TS group compared to the TF group, no statistically significant difference was found. Considering that the affected TM-CSA/FM-CSA ratios was equal in both groups, no significant difference was found (Table 3).

## Discussion

In the present study, TM-CSA and FM-CSA at all levels were found to be lower on the affected side, below the herniated level FM-CSA, and the ratio of FM-CSA/TM-CSA is significantly lower on the herniated side. In addition, the effect of multifidus cross-sectional areas on the success of TFESI has not been determined.

Studies on lumbar multifidus CSA and asymmetry have shown that multifidus muscles can be used as objective indicators of localized nerve root pathologies in patients with LDH, and morphological changes were detected in the multifidus muscle on the symptomatic side of the disc herniation segment.[12,15] It has been determined that the diameter of the multifidus muscle on the unaffected side is greater than on the opposite side due to disc herniation.[15] In animal studies, Dulor et al.[16] found that when the innervation of skeletal muscle is impaired, it leads to rapid muscle atrophy, and adipose tissue increases. Hodges et al.[17] found that multifidus CSA decreased after experimental disc and nerve root injury. Increased expression of proinflammatory cytokines causes a decrease in muscle diameter and increases adipose tissue infiltration.[18] James et al.[19] found that high amounts of macrophages and proinflammatory cytokines on the involved side play an active role in multifidus muscle remodeling following LDH. In addition, atrophy of the multifidus muscle may be observed after interventional treatment. Although this effect is not specifically related to steroids, radiofrequency ablation of the medial branch is thought to be responsible for this effect.[20] More studies are needed to obtain accurate information about the effects of steroids on the multifidus muscle. In our study, TM-CSA and FM-CSA at all levels were found to be lower on the affected side in the MRI measurements. Statistically, the affected side FM-CSA was found to be significantly lower below the disc herniation level. This result may be due to the fact that all of our patients had a disc herniation at the recess. Since, as we know, the multifidus has one level of innervation. If the spinal nerve is compressed in recess, the multifidus muscle at the below disc level is affected.[21]

When looking at muscle structure, the tendency of the multifidus to have more fat infiltration on the affected side can be demonstrated by the lower ratio of FM-CSA to TM-CSA. Congruent with the innervation of multifidus, Battié et al.[12] found that FM-CSA/TM-CSA ratio was statistically significantly lower at the level of herniation and below the herniation level on the affected side, supporting the results in our study.

Studies evaluating TS according to the severity of nerve compression (Priffman classification) are controversial. In some studies, it has been stated that those with grade 1–2 benefit more from treatment,[22] while in some studies, it is stated that grade 3–4 is more successful.[23] In some studies, as in our study, it has been shown that there is no relationship between grading and TS.[24]

Gellhorn et al.[13] applied TFESI to patients with lumbar spinal stenosis and found that multifidus CSA measurement is not an important predictor for pain scores at at 3 and 6 months. However, as we know, there is no study in the literature to examine the relationship between multifidus CSA and TFESI TS in LDH. In the present study, to evaluate this relationship, patients were divided into two groups according to an improvement of 50% or more in the 3-month NRS score. Considering the success of the treatment and multifidus muscle characteristics in the 3rd month, although the affected TM-CSA and FM-CSA were higher in the TS group compared to TF, no statistically significant difference was found between both groups. Considering the affected FM-CSA/TM-CSA ratios, no significant difference was found between the groups.

Our study has some limitations, first it is a retrospective study, and we could not evaluate other parameters except pain. Our other limitation was the absence of long-term patient follow-ups. Therefore, we could not investigate the effect of multifidus CSA on long-term TS. Although our study has some limitations, as we know, it is one of the precursor studies evaluating the relationship between TFESI and multifidus muscle diameter in patients with LDH.

## Conclusion

Below the herniated level FM-CSA and the ratio of FM-CSA/TM-CSA is lower at the herniated side in patients diagnosed with LDH. In addition, the effect of multifidus cross-sectional areas on the success of TFESI has not been determined. Since there is not much study on this subject, further research is needed to examine the effects of multifidus morphology on TFESI TS.

***Peer-rewiew: Externally peer-reviewed.***

***Ethics Committee Approval: The Marmara University Clinical Research Ethics Committee granted approval for this study (date: 06.11.2020, number: 09.2020.1158).***

***Conflict-of-interest issues regarding the authorship or article: None declared.***

## References

1. Tarulli AW, Raynor EM. Lumbosacral radiculopathy. Neurol Clin 2007;25:387–405. [CrossRef]
2. Friedrich JM, Harrast MA. Lumbar epidural steroid injections: Indications, contraindications, risks, and benefits. Curr Sports Med Rep 2010;9:43–9. [CrossRef]
3. Kim YH, Kim HJ, Seo J, Chai JW, Song HG, Choi YH, et al. Spinal nerve signal intensity on Dixon T2-weighted water-only sequence: An important outcome predictor after lumbar transforaminal epidural injection. Eur Radiol 2021;31:9459–67. [CrossRef]
4. Dickx N, Cagnie B, Achten E, Vandemaele P, Parlevliet T, Danneels L. Differentiation between deep and superficial fibers of the lumbar multifidus by magnetic resonance imaging. Eur Spine J 2010;19:122–8. [CrossRef]
5. Stevens S, Agten A, Timmermans A, Vandenabeele F. Unilateral changes of the multifidus in persons with lumbar disc herniation: A systematic review and meta-analysis. Spine J 2020;20:1573–85. [CrossRef]
6. Park MS, Moon SH, Kim TH, Oh J, Lee SJ, Chang HG, et al. Paraspinal muscles of patients with lumbar diseases. J Neurol Surg A Cent Eur Neurosurg 2018;79:323–9. [CrossRef]
7. Ranger TA, Cicuttini FM, Jensen TS, Peiris WL, Hussain SM, Fairley J, et al. Are the size and composition of the paraspinal muscles associated with low back pain? A systematic review. Spine J 2017;17:1729–48. [CrossRef]
8. Hyun JK, Lee JY, Lee SJ, Jeon JY. Asymmetric atrophy of multifidus muscle in patients with unilateral lumbosacral radiculopathy. Spine (Phila Pa 1976) 2007;32:E598–602. [CrossRef]
9. Altinkaya N, Cekinmez M. Lumbar multifidus muscle changes in unilateral lumbar disc herniation using magnetic resonance imaging. Skeletal Radiol 2016;45:73–7.
10. Burchiel KJ, Anderson VC, Brown FD, Fessler RG, Friedman WA, Pelofsky S, et al. Prospective, multicenter study of spinal cord stimulation for relief of chronic back and extremity pain. Spine (Phila Pa 1976) 1996;21:2786–94.
11. Pfirrmann CW, Dora C, Schmid MR, Zanetti M, Hodler J, Boos N. MR image-based grading of lumbar nerve root compromise due to disk herniation: Reliability study with surgical correlation. Radiology 2004;230:583–8. [CrossRef]
12. Battié MC, Niemelainen R, Gibbons LE, Dhillon S. Is level- and side-specific multifidus asymmetry a marker for lumbar disc pathology? Spine J 2012;12:932–9. [CrossRef]
13. Gellhorn AC, Suri P, Rundell SD, Olafsen N, Carlson MJ, Johnson S, et al. Lumbar muscle cross-sectional areas do not predict clinical outcomes in adults with spinal stenosis: A longitudinal study. PM R 2017;9:545–55. [CrossRef]

14. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 2016;15:155–63. [CrossRef]
15. Chen ZN, Yao XM, Lv Y, He BJ, Ye JC, Shao RX, et al. Morphology of the lumbar multifidus muscle in lumbar disc herniation at different durations and at different ages. Exp Ther Med 2018;15:4119–26. [CrossRef]
16. Dulor JP, Cambon B, Vigneron P, Reyne Y, Nouguès J, Casteilla L, et al. Expression of specific white adipose tissue genes in denervation-induced skeletal muscle fatty degeneration. FEBS Lett 1998;439:89–92. [CrossRef]
17. Hodges P, Holm AK, Hansson T, Holm S. Rapid atrophy of the lumbar multifidus follows experimental disc or nerve root injury. Spine (Phila Pa 1976) 2006;31:2926–33. [CrossRef]
18. Hodges PW, James G, Blomster L, Hall L, Schmid A, Shu C, et al. Multifidus muscle changes after back injury are characterized by structural remodeling of muscle, adipose and connective tissue, but not muscle atrophy: Molecular and morphological evidence. Spine (Phila Pa 1976) 2015;40:1057–71.
19. James G, Sluka KA, Blomster L, Hall L, Schmid AB, Shu CC, et al. Macrophage polarization contributes to local inflammation and structural change in the multifidus muscle after intervertebral disc injury. Eur Spine J 2018;27:1744–56. [CrossRef]
20. Deer TR, Gilmore CA, Desai MJ, Li SC, DePalma MJ, Hopkins TJ, et al. Percutaneous peripheral nerve stimulation of the medial branch nerves for the treatment of chronic axial back pain in patients after radiofrequency ablation. Pain Med 2021;22:548–60. [CrossRef]
21. Farshad M, Gerber C, Farshad-Amacker NA, Dietrich TJ, Laufer-Molnar V, Min K. Asymmetry of the multifidus muscle in lumbar radicular nerve compression. Skeletal Radiol 2014;43:49–53. [CrossRef]
22. Ghahreman A, Bogduk N. Predictors of a favorable response to transforaminal injection of steroids in patients with lumbar radicular pain due to disc herniation. Pain Med 2011;12:871–9. [CrossRef]
23. Lee JW, Choi SW, Park SH, Lee GY, Kang HS. MR-based outcome predictors of lumbar transforaminal epidural steroid injection for lumbar radiculopathy caused by herniated intervertebral disc. Eur Radiol 2013;23:205–11. [CrossRef]
24. Şencan S, Çelenlioğlu AE, Asadov R, Gündüz OH. Predictive factors for treatment success of transforaminal epidural steroid injection in lumbar disc herniation-induced sciatica. Turk J Med Sci 2020;50:126–31.