Observational Study

The Role of the Subcutaneous Fat Index in Predicting Transforaminal Epidural Steroid Injection Treatment Success: An Observational Prospective Study

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Disclaimer: There was no external funding in the preparation of this article.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Article received: 10-30-2024
Revised article received: 02-03-2025
Accepted for publication: 03-05-2025

Free full article: www.painphysicianjournal.com

Background: Obesity is thought to be one factor that contributes to low back pain (LBP). Classifying obesity according to body mass index (BMI) and its use in general health-related predictions is often considered inadequate. For this reason, a new parameter known as the subcutaneous fat index (SFI) has been defined to provide insight into spine health. SFI is the thickness of subcutaneous fat tissue (SFTT) at the L1-L2 level.

Objectives: This study aimed to investigate the answer to the question "Is this new index, which has been shown to be successful in predicting spinal degeneration and morphological changes, effective in predicting the success of transforaminal epidural steroid injection (TFESI) treatment?"

Study Design: An observational prospective clinical study.

Setting: A university hospital's interventional pain management center.

Methods: Patients with spinal radicular pain due to intervertebral disc herniation, for whom TFESI was planned, were categorized into two groups according to SFI (was measured as the vertical distance from the tip of the spinous process of the L1 vertebra to the skin on axial T2-weighted lumbar spine magnetic resonance images cut-off values (9.4 mm in men and 8.45 mm in women) and were followed up for 3 months after the procedure. During patient follow-up, evaluations were performed with the Numeric Rating Scale, Oswetry Disability Index, and 12-Item Short-Form Health Survey. Additionally, intervertebral disc degeneration (IVDD) related to injection level and nerve compression grading were evaluated radiologically.

Results: A total of 50 patients' IVDD as related to injection level was significantly higher in the SFI > 9.4/8.45 mm group. According to the 3rd month's follow-up results, significant treatment success was observed in all parameters in both groups. However, no significant difference was found in predicting treatment success between the SFI < 9.4/8.45 mm and SFI > 9.4/8.45 mm groups.

Limitations: Our sample sizes were asymmetric, and a single radiologist performed the evaluation.

Conclusion: The newly defined SFI parameter was not effective enough to provide a significant difference in nerve compression grading or in predicting treatment success.

Key words: Intervertebral disc herniation, low back pain, radicular pain, nerve compression, transforaminal epidural steroid injection, obesity, subcutaneous fat

Pain Physician 2025: 28:E421-E430

Lumbosacral radicular pain is defined as pain originating from the lumbar level and radiating to the lower extremities along the sensory distribution area of one or more spinal nerves (1-3). Sciatica caused by lumbar disc herniation appears as a general health problem with a lifetime prevalence of approximately 12.2%-43% and an annual prevalence of 2.2%-34% (4). In the treatment of the relevant clinic, medical agents, physical therapy modalities, epidural steroid injections (ESIs) and surgical methods can be used. ESIs are administered for pain management after other conservative modalities have failed (5). These injections can be performed with different approaches: caudal, interlaminar and transforaminal. A review evaluating the treatment effectiveness showed level 1 (highest level of evidence) evidence from high-quality randomized controlled trials supporting the use of transforaminal epidural steroid injection (TFESI) for radicular pain caused by disc herniations (6).

Obesity, one of the factors thought to predispose patients to the formation of low back pain (LBP) and lumbosacral radicular pain, has been evaluated in various studies. A meta-analysis that examined 95 studies and included 33 showed that LBP was more prevalent in overweight people than in non-overweight people. The same meta-analysis also showed that overweight and obesity had the strongest associations with LBP and the seeking of medical care for chronic LBP (7). However, in a study examining the influence of obesity on the effectiveness of TFESIs, no significant difference was found in the percentage of improvement in pain after a TFESI or in the proportion of cases with a 50% or more reduction in pain when the overweight and obese groups were compared with the normal-weight group (8). Body mass index (BMI), though used in the evaluation of obesity, does not provide information about the ratios of body composition (9). Therefore, there have been efforts to define more specific parameters.

It has been shown that the subcutaneous fat tissue thickness (SFTT) at the upper lumbar levels (especially L1-L2) has a significant relationship with severe degeneration of the L5-S1 level intervertebral disc and vertebral surface changes in the L4-L5 L5-S1 areas. Therefore, when examining patients who present with LBP, their SFTT is more valuable to evaluate than their BMI (10). Proceeding from here, a new anthropometric index was defined, and the L1-L2 level SFTT was named the subcutaneous fat index (SFI). The limit value of this index is determined as 9.4 mm in men and 8.45 mm in women. Individuals above the limit value have been shown to exhibit significantly more intervertebral disc disorders and vertebral surface changes (11).

Our study investigated the relationship between SFI and treatment success experienced by patients who received TFESIs for spinal radicular pain caused by lumbar intervertebral disc herniation. To the best of our knowledge, this study is the first to evaluate the aforementioned relationship.

Methods

Patient Cohort

The study was approved by the institutional review board of our university (approval date: September 2, 2022; approval no: 09.2022.1168) and was carried out in compliance with the Helsinki Declaration. The trial was registered with ClinicalTrials.gov under number NCT05556538. Patients who received a detailed physical examination and magnetic resonance imaging (MRI) and were diagnosed with lumbosacral radiculopathy due to disc herniation were included, provided that they had applied to pain-medicine, physical-medicine, and rehabilitation outpatient clinics with complaints of LBP and unilateral leg pain. TFESIs were planned for these patients, and our study was conducted prospectively. The inclusion criteria were as follows: being between the ages of 18 and 65, having been diagnosed with lumbosacral radiculopathy accompanied by LBP and leg pain that has been present for at least 3 months and has not responded to other conservative treatment methods, having nerve compression caused by lumbar paracentral disc herniation and a single-level injection planned by a pain medicine specialist, and completing a 3-month clinical follow-up after the procedure. Meanwhile, the exclusion criteria comprised the following conditions: having had lumbosacral surgery; undergoing multi-level and bilateral injections as a current patient; presenting with a central, foraminal or extraforaminal disc herniation; presenting with a local and/or systemic infection; having a history of malignancy; presenting with spinal stenosis; being pregnant; having a known experience with coagulopathy; having a history of known psychiatric disease; having a history of allergy to any of the injectables; and having received an epidural steroid injection within the last 3 months.

Since our study was the first to prospectively examine the effect of a newly defined parameter on treatment success, our sample size was determined with the prediction of the power analysis we made based on the results of Gharibo et al's 2011 study (12). G*Power soft-

ware Version 3.1.9.6 was employed for this purpose. When we predicted that the difference in the numeric rating scale (NRS) would be 20%, we planned our study with 44 patients for α = 0.05 and Power = 0.80. With possible dropouts included, the planned study group was determined to be 52 patients.

Imaging Modality and Technique

All images were acquired with 1.5 T and 3.0 T MRI Philips Ingenia scanners (Philips Healthcare), using dedicated spinal coils with standard lumbar MRI protocol and without contrast material. All studies included T2-weighted turbo spin echo (TSE) counterimages of whole spinal columns. For the lumbosacral vertebral area, sagittal and axial TSE images were obtained, some T1-weighted (TR/TE: 420/9 ms) and others T2-weighted (TR/TE: 3200/90). Each axial image had a matrix of 256 x 133 with a slice thickness of 4 mm and a gap of 0.4 mm, and each sagittal image had a matrix of 256 x 320 with a slice thickness of 5 mm and a gap of 0.5 mm.

All images were evaluated by a radiologist (EB) who had 9 years of spinal imaging experience and did not know the patients' clinical follow-up data. Sagittal cervicothoracic counterimages were used as the gold standard method for vertebral numbering. In accordance with the definition Berikol et al provided in their 2022 study (11), the SFI was measured as the vertical distance from the tip of the L1 vertebra's spinous process to the skin on axial T2-weighted lumbar spine MRIs (Fig. 1).

The grade of nerve compression was assessed on axial T2-weighted images and sagittal T1- weighted images. The severity of nerve root compression caused by paracentral disc herniation was evaluated using the grading system published by Pfirrmann et al in 2004 (13) and validated by Lurie et al in 2008 (14). This system defines the grades as follows: Grade I indicates that the disc simply makes contact with the nerve root; grade II indicates the nerve root is displaced but with preservation of periradicular cerebrospinal fluid (CSF) or fat; grade III indicates obliteration of the periradicular CSF or fat; and grade IV indicates morphological distortion of the nerve root. For paracentral herniations, grades I and II were classified as "low-grade" and grades III and IV as "high-grade" nerve compression. These classifications were based on the statistically significant treatment responses found by Ghahreman and Bogduk in 2011 (15).

Additionally, from the L1-L2 to L5-S1 disc levels, intervertebral disc degeneration (IVDD) was also assessed on T2-weighted sagittal images according to the grading system published by Pfirrmann et al in 2001 (16). According to this system, grade I indicates a homogeneous bright white disc with clear distinction of the nucleus and anulus and a normal height for the intervertebral disc; grade II indicates an inhomogeneous (with or without horizontal bands) disc with clear distinction of the nucleus and anulus and a normal height for the intervertebral disc; grade III indicates an inhomogeneous gray disc with unclear distinction of the nucleus and anulus and a normal-to-slightly-decreased height for the intervertebral disc; grade IV indicates an inhomogeneous gray-to-black disc without distinction of the nucleus and anulus and a normal-to-moderately-decreased height for the intervertebral disc; and grade V indicates an inhomogeneous black disc without distinction of the nucleus and anulus and collapsed disc space.

TFESI

The fluoroscopy device was positioned with a 10-30° oblique and 0-15° craniocaudal angle, and the neural foramen was visualized. The injection site and subcutaneous tissue were infiltrated with a local anesthetic (3 mL of 2% prilocaine). A 21-G 90 mm/120 mm spinal needle was inserted to the subpedicular area under intermittent fluoroscopic visualization with the

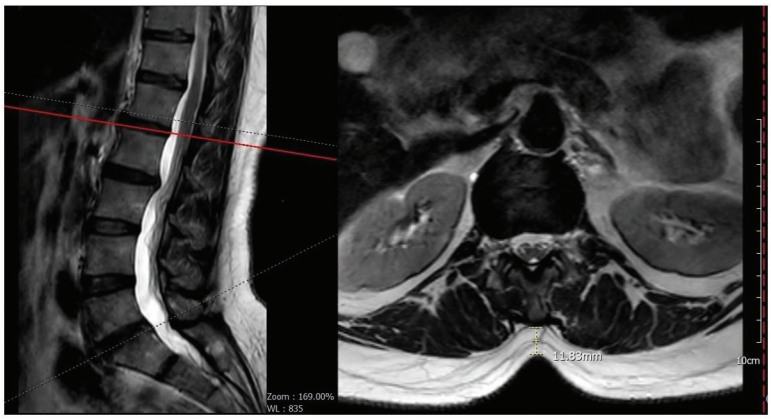

Fig. 1. *Measurement technique of L1-L2 level subcutaneous fat thickness (SFI) on T2-weighted axial lumbar MRI.*

co-axial technique (directed to the 6 o'clock position). While the epidural area was approached, the position of the needle was confirmed with lateral imaging. Contrast dye (0.5 to 1 mL) was administered to confirm that the needle was inside the epidural space in the posteroanterior and lateral images. After the confirmation of the presence of the epidural distribution without vascular, subdural, or intrathecal distribution, a mixture of 10 mg dexamethasone, 1 mL saline solution, and 1 mL (0.5%) bupivacaine solution was injected. Once the procedure was finished, patients were referred to the observation room and followed for one hour. Patients who developed no complications were discharged following their first-hour examination, with recommendations.

Patient Follow-ups

The patients were classified into 2 groups: individuals below the SFI limit values (9.4 mm in men, 8.45 mm in women) and individuals above those values. The Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), and 12-Item Short-Form Health Survey (SF-12) and methods were administered before the procedure, as well as one hour (NRS only), 3 weeks, and 3 months after the procedure.

NRS is a scale used to rate lower back and leg pain, scored between 0 and 10, on which 0 is defined as no pain and 10 as the most severe and unbearable pain.

ODI is a deficiency/sufficiency index that includes evaluations grouped according to daily activity types and levels in patients with LBP. Zero percent to 20% indicates minimal disability, 20% to 40% indicates moderate disability, 40% to 60% indicates severe disability, 60% to 80% indicates crippled patients, and 80% to 100% indicates bedbound patients (17).

SF-12 is a general health questionnaire that evaluates the patient's quality of life. On this survey, 2 separate evaluation scores are obtained: mental and physical. The population average of physical SF-12 (pSF-12) and mental SF-12 (mSF-12) are both 50 points, with a standard deviation of 10 points. Scores above 50 indicate an increase in health-related quality of life, while scores below 50 indicate a decrease (18).

Based on studies evaluating the clinical effectiveness of TFESIs, a reduction of at least 50% in the NRS score and a reduction of at least 40% in the ODI score were taken as criteria to evaluate treatment success at the third month (19,20).

The follow-up of the treatment results, which we evaluated with NRS, SF-12 and ODI parameters between the 2 groups, was done blindly, without knowing which patient was in which group. (SS and SK performed the TFESI procedure, EB performed the SFTT-SFI measurements, IVDD grading, and nerve root compression staging, and AS performed the clinical follow-ups).

Statistical Analysis

Data were analyzed on the computer using Excel 2016 (Microsoft) and GraphPad Prism version 7.00 for Windows, (GraphPad Software). Compliance of the data with normal distribution was evaluated with the Shapiro-Wilks test. Descriptive statistics are shown as mean ± standard deviation (SD) for continuous variables. Homogeneity of variances between groups was evaluated with the Levene test. Unpaired t-tests were performed to compare measurements with normal distribution between the 2 groups, but if those measurements were not normally distributed, the Mann-Whitney U test was used to compare the groups instead. Fisher's exact test was used to compare the proportions of the groups. For normally distributed data, changes in the measurements over time were investigated using a repeated measures ANOVA. The Greenhouse-Geisser correction was used when the sphericity assumption was violated. The post-hoc Tukey test was applied to the variables that were found to be statistically significant for multiple comparisons. The interaction between groups and subgroups was evaluated with a 2-way ANOVA. For variables that were not normally distributed, Kruskal-Wallis tests were conducted to compare these parameters among BMI groups. Dunn's multiple comparison test was applied to the variables that were found to be statistically significant. $P < 0.05$ was considered statistically significant.

Results

A total of 1093 patients who underwent ESI during this period (October 2022-May 2023) were evaluated in terms of study eligibility criteria until we reached our target patient number of 52. Of these patients, 704 underwent TFESIs, and only 256 of these were single-level and unilateral injections. Patient follow-ups were completed in August 2023. Two of these patients were excluded from the study because they did not complete their 3-month follow-up (Fig. 2). After the clinical follow-up of all patients included in the study was completed, the researchers shared the data with one another, and the entire information set was brought together. A total of 50 patients, 35 women and 15 men, were included in the evaluation, and the average dura-

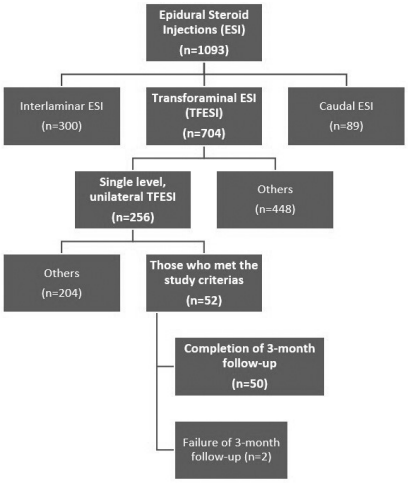

Fig. 2. *Patient flow chart.*

tion of their symptoms was 20.98 ± 23.87 months. A TFESI was performed on one patient at the L2/3 level, 3 patients at the L3/4 level, 2 patients at the L4/5 level, 33 patients at the L5/S1 level, and 11 patients at the S1 foraminal level. Of the total injections, 27 were administered to the left side and 23 to the right side. When the patients were divided into 2 groups according to the reference value of 9.4/8.45 mm, there were 33 patients in the SFI > 9.4/8.45 mm group and 17 patients in the SFI < 9.4/8.45 mm group. When the groups were compared in terms of demographic and clinical data, we found only that the severity of IVDD in relation to the injection level was significantly higher in SFI > 9.4/8.45 mm group (Table 1).

We defined success as a reduction of 50% or more in the NRS score and 40% or more in the ODI score at the third month. According to the NRS results at the third-month follow-up, treatment success was achieved in 15 out of 17 patients (88%) in the SFI < 9.4/8.45 mm group and 23 out of 33 patients (70%) in the SFI > 9.4/8.45 mm group. Meanwhile, the third-month ODI results showed treatment success in 13 out of 17 patients (76%) in the SFI < 9.4/8.45 mm group and in 22 out of 33 patients (67%) in the SFI > 9.4/8.45 mm group. Changes and statistical analysis of all parameters within and between the groups over time are presented in Table 2. Using 2-way ANOVA graphics, Figs. 3, 4, and 5 show the changes in the groups' variables relative to one another over time.

Additionally, when we divided the patients into 3 groups according to their BMI values, the distribution was as follows: BMI < 25 kg/m^2 group: 5 patients (3 female, 2 male), average BMI: 23.72 ± 1.36; BMI 25-30 kg/m^2 group: 27 patients (18 female, 9 male), average BMI: 27.62 ± 1.52; BMI > 30 kg/m^2 group: 18 patients (14 female, 4 male), average BMI: 34.44 ± 4.03. According to the third-month NRS and ODI results, the respective ratios of treatment success for the BMI < 25 kg/m^2 group was 5/5 patients (100%) and 3/5 patients (60%). In the BMI 25-30 kg/m^2 group, these ratios were 18/27 patients (67%) and 19/27 patients (70%); and in the BMI > 30 kg/m^2 group, they were 15/18 patients (83%) and 13/18 patients (72%). The results and statistical analysis of all parameters in grouping according to BMI are given in Table 3.

Table 1. *The demographic and clinical data of all patients.*

Descriptive Parameters	SFI < 9.4/8.45mm Group (n = 17)	SFI > 9.4/8.45mm Group (n = 33)	*P*-value
Age (years) (Mean ± SD)	44.18 ± 10.12	48.06 ± 12.55	0.244[a]
Gender n (%) Female Male	 12 (70.6) 5 (29.4)	 23 (69.7) 10 (30.3)	> 0.999[b]
Symptom Duration (months) (Mean ± SD)	20.12 ± 22.18	21.42 ± 25.01	0.851a
Intervertebral Disc Degeneration (Mean ± SD) (related to injection level)	2.65 ± 0.86	3.24 ± 0.94	0.022[c*]
Nerve Compression Grades (Mean ± SD) (low-grade %/high-grade %)	2.88 ± 1.22 (41%-59%)	2.58 ± 1.23 (48%-52%)	0.392[c]
Preprocedural NRS (Mean ± SD)	8.294 ± 1.359	8.636 ± 1.245	0.376[a]
Preprocedural ODI (Mean ± SD)	74.94 ± 10.96	75.15 ± 10.45	0.947[a]
Preprocedural pSF-12 (Mean ± SD)	27.09 ± 4.859	27.19 ± 5.534	0.946[a]
Preprocedural mSF-12 (Mean ± SD)	38.28 ± 9.638	33.54 ± 10.52	0.127[a]

[a]Unpaired t-test. [b]Fisher's exact test. [c]Mann-Whitney U test. *Statistically significant. SFI, subcutaneous fat index.

Discussion

BMI, which is used in the evaluation of obesity, does not provide information about the proportions of body composition, and research for defining more specific parameters to make predictions about the health status of a patient is in progress (9). One of these stud-

ies showed a high correlation between body fat percentage and waist SFTT (21). Another study reported that regional body fat measurements such as visceral fat thickness, SFTT, waist-hip ratio, and waist circumference showed better correlation with the general health status of patients than did BMI (22,23). In the results of a different study, abdominal fat tissue thickness was found to be closely related to IVDD (24). To evaluate health status with new parameters, detailed yet practical approaches are needed. In their 2022 study, Özcan-Ekşi et al (10) evaluated the lumbar SFTT, which they investigated separately at each level. They concluded that the thickness, especially at the L1-L2 level, was a superior indicator of spine health or degeneration than BMI. Based on this information, Berikol et al, in their 2022 study (11), named this SFTT value as an index specific to the L1-L2 level and determined gender-specific limit values that would correlate with spinal degeneration.

When we focus on the treatment part, as Helm li et al published in 2021 (6), we know that the effectiveness of TFESIs for radicular pain caused by disc herniation has been proven at a high level of evidence. We have mentioned that obesity classification ac-

Table 2. *NRS, ODI, pSF-12 and mSF-12 scores and statistics of their changes within and between groups over time.*

	SFI < 9.4/8.45mm Group (n = 17)	SFI > 9.4/8.45mm Group (n = 33)	*P*-value**	*P*-value***
NRS (Mean ± SD)				0.242
Preprocedural	8.294 ± 1.359[a]	8.636 ± 1.245[a]	0.376	
First hour	0.471 ± 1.179[b]	0.454 ± 1.003[b]	0.960	
3rd week	3.471 ± 2.764[c]	2.636 ± 2.702[c]	0.310	
3rd month	2.471 ± 2.035[c]	3.273 ± 3.115[c]	0.342	
P-value*	< 0.001	< 0.001		
ODI (Mean ± SD)				0.414
Preprocedural	74.94 ± 10.96[a]	75.15 ± 10.45[a]	0.947	
3rd week	30.94 ± 19.56[b]	26.85 ± 16.64[b]	0.442	
3rd month	28.00 ± 17.65[b]	31.64 ± 23.28[b]	0.575	
P-value*	< 0.001	< 0.001		
pSF-12 (Mean ± SD)				0.350
Preprocedural	27.09 ± 4.859[a]	27.19 ± 5.534[a]	0.946	
3rd week	43.43 ± 10.33[b]	45.96 ± 10.21[b]	0.413	
3rd month	46.98 ± 8.507[b]	45.03 ± 11.26[b]	0.535	
P-value*	< 0.001	< 0.001		
mSF-12 (Mean±SD)				0.160
Preprocedural	38.28 ± 9.638[a]	33.54 ± 10.52[a]	0.127	
3rd week	47.95 ± 13.82[b]	50.68 ± 8.965[b]	0.402	
3rd month	49.22 ± 11.97[b]	48.59 ± 11.83[b]	0.859	
P-value*	0.005	< 0.001		

*Repeated measures ANOVA. **Unpaired t-test. ***Two-way ANOVA (time x group interaction). Each subscript letter denotes a subset time with means that do not differ significantly from each other at the 0.05 level. SFI, subcutaneous fat index.

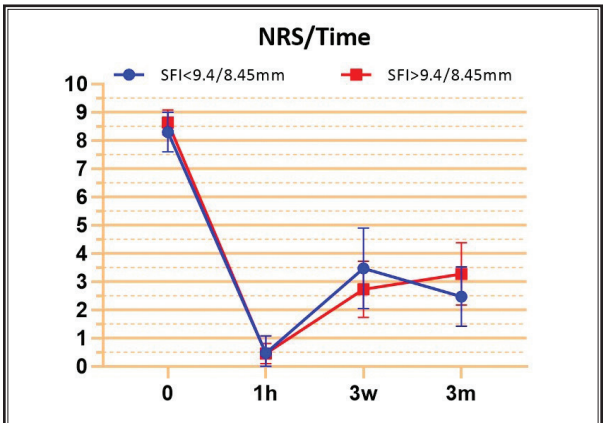

Fig. 3. *Two-way ANOVA analysis of NRS results*

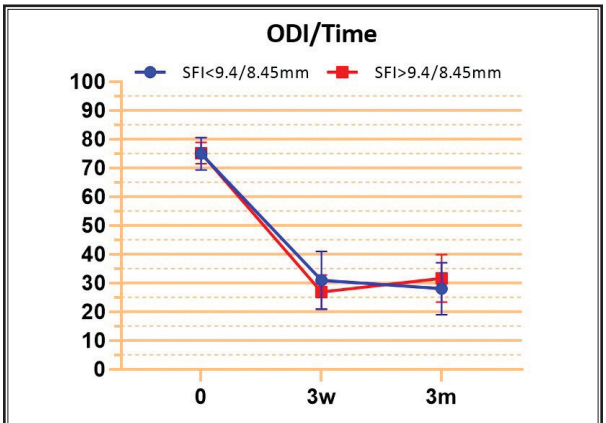

Fig. 4. *Two-way ANOVA analysis of ODI results*

cording to BMI and the evaluation of its effect on the success of TFESI-based treatment did not yield meaningful results (8). We studied the SFI, which was shown to be successful in predicting spinal degeneration, as one of the parameters that may affect the prognosis of patients' improvement in pain relief and recovery of functionality. We know that in surgical approaches, the probability of developing perioperative complications is higher for obese patients, especially if comorbid conditions are present (25-27). For these reasons, based on the results of our planned study, we aim to develop a practical approach to predict the level of treatment success that TFESIs can achieve for patients before physicians resort to surgery. Various studies have been conducted to predict the effects of ESI and TFESI results on treatment success (28-36), but not many. All the factors and points that need further evaluation can be considered elements that have motivated us to plan and carry out our study. According to the results of our study, a significant decrease from the initial values was observed in pain scores as well as ODI scores in both groups at all clinical follow-up assessments after the procedure. Similarly, for both groups, significant improvements over the initial values were observed in the SF-12 scores, which are used to evaluate the patients' mental and physical quality of life, at all clinical follow-up assessments after the procedure. The significant improvements in all the aforementioned parameters in all patients are consistent with the literature (6,20). In summary, treatment efficacy was demonstrated to some degree in all patients in all parameters we evaluated. However, when the patients were grouped

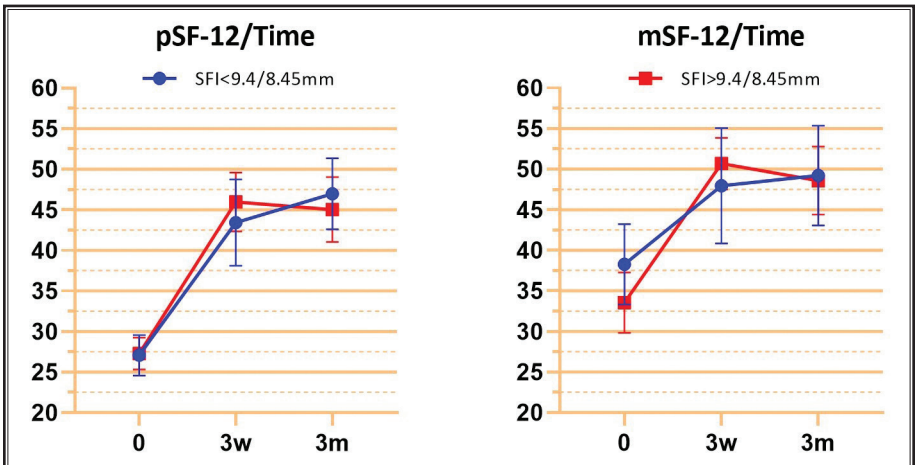

Fig. 5. *Two-way ANOVA analysis of SF-12 results*

Table 3. *NRS, ODI, pSF-12 and mSF-12 scores, nerve compression grades, and statistics according to the BMI groups.*

	BMI < 25 kg/m² Group (n = 5)	BMI 25-30 kg/m² Group (n = 27)	BMI > 30 kg/m² Group (n = 18)	*P*-value*
Nerve Compression Grades (Mean ± SD) (low-grade % - high-grade %)	3.80 ± 0.45 (0% - 100%)	2.48 ± 1.19 (56% - 44%)	2.67 ± 1.28 (45% - 55%)	0.086
NRS (Mean ± SD)				
Preprocedural	8.40 ± 1.14	8.41 ± 1.42	8.72 ± 1.13	0.757
First hour	0.80 ± 1.30	0.44 ± 1.05	0.39 ± 1.04	0.545
3rd week	4.20 ± 3.77	3.44 ± 2.56	1.78 ± 2.39	0.055
3rd month	2.20 ± 1.64	3.48 ± 2.82	2.50 ± 2.99	0.294
ODI (Mean ± SD)				
Preprocedural	70.40 ± 6.39	76.37 ± 10.87	74.44 ± 10.90	0.370
3rd week	33.20 ± 22.74	30.67 ± 17.52	23.22 ± 16.06	0.344
3rd month	31.60 ± 21.42	33.48 ± 20.57	25.44 ± 22.91	0.425
pSF-12 (Mean ± SD)				
Preprocedural	29.32 ± 3.49	27.33 ± 4.99	26.29 ± 6.06	0.373
3rd week	40.45 ± 14.01	43.70 ± 10.46	48.50 ± 8.10	0.237
3rd month	43.81 ± 11.89	45.15 ± 10.24	47.03 ± 10.59	0.770
mSF-12 (Mean ± SD)				
Preprocedural	40.01 ± 9.86	35.88 ± 9.40	32.72 ± 11.76	0.350
3rd week	43.56 ± 15.22	48.84 ± 11.47	52.85 ± 7.60	0.398
3rd month	46.61 ± 15.66	46.84 ± 12.13	52.34 ± 9.75	0.309

*Kruskal-Wallis test.

according to SFI, no difference in nerve compression grading or in treatment success was observed between the groups. In addition, when we classified our study group according to BMI, no difference was observed in NRS, ODI and SF-12 score changes between the groups at any of the time periods. According to BMI or SFI grouping, the results show that patients can benefit from this treatment whether they are obese or not, and that the prejudice that obese people will not benefit from the treatment is wrong.

Judging by the findings of our research and previous studies based on BMI, the effectiveness of TFESIs has limited or no correlation with BMI (8,28) or SFI. Nonetheless, we do see that BMI is positively correlated with LBP (7). It seems possible to associate the positive correlation with LBP with more IVDD and morphological changes due to the high biomechanical traumatic effect of obesity. However, the lack of a significant difference in treatment results, despite the increasing difficulties in the procedure technique and the deepening of the epidural distance (37,38), can be explained by the fact that a TFESI can provide direct access to the pathology area after the physician obtains a radicular contrast distribution pattern under satisfying fluoroscopic imaging. After obtaining a good neurogram with the correct needle size, the physician can also gain coverage of the area responsible for pain. Furthermore, the effect of a TFESI can be summarized by the anti-inflammatory and neural-membrane-stabilizing properties of steroids, as well as the increasing blood flow to the ischemic spinal nerve root of local anesthetics and the cytokine-removing effect of the injection material in the area (28,39,40). Once all these variables and especially the local factors are taken into consideration, it becomes understandable why there is no significant difference in treatment results.

When we examined the results according to the limit values of 50% or greater reduction in the NRS score and 40% or greater reduction in the ODI score, which we accepted as treatment success, we found that in the third-month results, the percentage of treatment success was higher in the SFI < 9.4/8.45 mm group. When we look at the BMI groups' results in terms of the percentage of patients with treatment success, we cannot predict a significant difference in improvement between the time periods. Additionally, in parallel with the success of using SFI to predict morphological changes, our study also showed that the severity of IVDD related to injection level was significantly higher in the SFI > 9.4/8.45 mm group, supporting the results of Berikol et al's 2022 study (11).

Our study has some limitations. To ensure that the injection procedures and patient follow-ups did not lose their objectivity and that the study could be continued blindly, the relevant researchers continued the process without being aware of the radiological measurements and groupings until all clinical follow-ups of all patients were completed. Radiology data and clinical follow-up data were brought together at the end of the study. For this reason, since we cannot determine the sample number/distribution of our study groups, the groups have an asymmetric sample number. However, this situation did not cause any negative effects in obtaining and interpreting the results statistically. The results are far from showing a significant difference. Secondly, since we used non-particulate steroids, our patient follow-ups were limited to 3 months. To perform long-term clinical effect follow-up, repeated injections would have to be made, but this method was not preferred because environmental and individual factors could have affected the clarity of the results as the duration of the study was extended. Lastly, it would have been better if a second radiologist had reviewed the images, despite the 9 years of experience accumulated by the one radiologist who evaluated the images in the study. Conducting studies in a homogeneous and specific group, as in our study, but with larger patient populations and longer-term clinical follow-up, will shed more light on the subject by increasing knowledge about the use of SFI in predicting treatment success.

Conclusion

In our prospective clinical study, the newly defined SFI parameter, which was shown to be associated with spinal degeneration, was also found to have a positive correlation with the severity of IVDD related to injection level. However, it was observed that SFI was not effective enough to provide a significant difference in nerve compression grading or in predicting treatment success.

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