

EFFICACY OF EXTRACORPOREAL SHOCK WAVE THERAPY IN CHRONIC NON-RADICULAR LOW BACK PAIN

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Kronik Radiküler Olmayan Bel Ağrısında Ekstrakorporeal Şok Dalgası Tedavisinin Etkinliği

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ABSTRACT

Objective: Extracorporeal shock wave therapy (ESWT) is a modern physical therapy modality used to treat musculoskeletal conditions. In this study, we aimed to assess the effectiveness of radial ESWT on pain, disability and depression in chronic non-radicular low back pain (LBP).

Material and Methods: Sixty-nine patients with chronic nonradicular LBP were included in the study and randomized to two groups: rESWT (group 1) or sham ESWT (group 2). A total of 62 patients completed the study; the intervention group (n=30, mean age of 45.7±10.7 years) received rESWT, and the control group (n=32, mean age of 47.0±10.1 years) received sham ESWT. Outcome parameters included the Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and Hospital Anxiety and Depression Scale (HADS). The evolutions were made before treatment, after treatment, and 1st month after treatment.

Results: Sixty-two patients completed the study (rESWT, n=30; sham ESWT, n=32). Pain intensity decreased significantly more in the rESWT group than in the sham group both immediately after treatment (VAS change: 2.9±1.3 vs. 1.8±1.4, p=0.002) and at 1-month follow-up (3.3±1.7 vs. 2.3±1.9, p=0.035). Functional disability also improved significantly more with rESWT (ODI change after treatment: 6.5 [4.0-12.0] vs. 2.0 [-2.0-3.5], p<0.001; at 1 month: 8.0 [0.0-12.5] vs. 0.0 [0.0-5.5], p=0.014). Although anxiety improved more in the rESWT group immediately after treatment (p=0.036), this difference was not maintained at 1 month (p=0.184). No significant between-group differences were observed in depression scores either after treatment (p=0.994) or at 1 month (p=0.177).

Conclusion: rESWT appears to be an effective intervention for reducing pain and disability, with superior short-term outcomes compared to sham treatment. However, its effects on anxiety were transient, and no additional benefit was observed for depression. rESWT may be considered a safe and effective adjunctive treatment for improving pain and function in this patient population.

Keywords: Low Back Pain; Extracorporeal Shock Wave Therapy; Sham Therapy; Pain; Disability

ÖZ

Amaç: Ekstrakorporeal şok dalgası tedavisi (ESWT), kas-iskelet sistemi rahatsızlıklarının tedavisinde faydalı olan yeni ve modern bir fizik tedavi yöntemidir. Bu çalışmada, radyal ESWT'nin kronik radiküler olmayan bel ağrısında ağrı, engellilik ve depresyon üzerindeki etkinliğini değerlendirmeyi amaçladık.

Gereç ve Yöntemler: Kronik radiküler olmayan bel ağrısı olan 69 hasta çalışmaya dahil edildi ve rESWT (grup 1) veya plasebo (sham) ESWT (grup 2) olacak şekilde iki gruba randomize edildi. Toplam 62 hasta çalışmayı tamamladı; müdahale grubu olan grup 1 (n=30, yaş ortalaması 45,7±10,7 yıl) rESWT ile, kontrol grubu olan grup 2 (n=32, yaş ortalaması 47,0±10,1 yıl) ise plasebo ESWT ile tedavi edildi. Sonuç parametreleri Görsel Analog Skalası (VAS), Oswestry Engellilik İndeksi (ODI) ve Hastane Anksiyete ve Depresyon Ölçeği (HADS) içeriyordu. Değerlendirmeler tedavi öncesinde, tedavi sonrasında ve tedaviyi takiben 1. ayda yapıldı.

Bulgular: Çalışmayı toplam 62 hasta tamamladı (rESWT, n=30; sham ESWT, n=32). Ağrı şiddetindeki azalma rESWT grubunda hem tedavi sonrasında (VAS değişimi: 2,9±1,3'e karşı 1,8±1,4, p=0,002) hem de 1. ay kontrolünde (3,3±1,7'ye karşı 2,3±1,9, p=0,035) anlamlı olarak daha fazlaydı. Fonksiyonel yetersizlikteki iyileşme de rESWT grubunda daha belirgindi (ODI değişimi; tedavi sonrası: 6,5 [4,0-12,0]'ye karşı 2,0 [-2,0-3,5], p<0,001; 1.ay: 8,0 [0,0-12,5]'ye karşı 0,0 [0,0-5,5], p=0,014). Anksiyete skorlarındaki iyileşme tedavi sonrasında rESWT grubunda daha fazla olmasına rağmen (p=0,036), bu fark 1. ayda devam etmedi (p=0,184). Depresyon skorlarındaki değişim açısından ise tedavi sonrası (p=0,994) ve 1. ayda (p=0,177) gruplar arasında anlamlı fark saptanmadı.

Sonuç: rESWT, ağrı ve sakatlığı azaltmada etkili bir müdahale gibi görünmektedir ve plasebo tedavisine kıyasla kısa vadeli sonuçları daha üstündür. Bununla birlikte, anksiyete üzerindeki etkileri geçicidir ve depresyon için ek bir fayda gözlemlenmemiştir. rESWT, bu hasta popülasyonunda ağrı ve fonksiyonu iyileştirmek için güvenli ve etkili bir yardımcı tedavi olarak düşünülebilir.

Anahtar Kelimeler: Bel Ağrısı; Ekstrakorporeal Şok Dalgası Tedavisi; Plasebo (Sham) Tedavi; Ağrı; Engellilik

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INTRODUCTION

Non-radicular low back pain (LBP) refers to pain localized in the lumbosacral region without clinical or radiographic evidence of nerve root compression. Unlike radicular pain, which is typically associated with neuropathic features such as radiating leg pain, paresthesia, or neurologic deficits, nonradicular LBP is usually mechanical or nonspecific. LBP is one of the most common musculoskeletal complaints worldwide, with up to 80% of adults experiencing at least one episode in their lifetime (1). The majority of cases are nonradicular, accounting for approximately 85-90% of primary care presentations (2).

A comprehensive systematic review on LBP reported a marked rise in its prevalence, incidence, and associated years lived with disability over the past three decades. By 2019, LBP remained the foremost global contributor to years lived with disability. The review also highlighted that prevalence tends to increase progressively with age, reaching its highest levels among individuals aged 45 to 54 years in both men and women (3).

The etiology of nonradicular LBP is multifactorial and often nonspecific. Contributing factors include muscle or ligament strain, intervertebral disc degeneration, facet joint arthropathy, and biomechanical stressors (4). Psychosocial variables such as stress, occupational demands, and low job satisfaction also play a significant role in the persistence and chronicity of symptoms (5). Patients with nonradicular LBP typically report localized pain in the lumbar region (usually between the last rib margin and the gluteal fold), the lower back, and the buttocks, which may be mechanical (worse with activity, improved with rest) and often lack neurological signs. Pain is usually confined to the back and may be accompanied by stiffness or a limited range of motion. According to a previous study, LBP is one of the leading contributors to disability-adjusted life years on a global

scale (6). Given its substantial economic impact and the psychological distress it imposes globally, there is a pressing need to prioritize therapeutic strategies that provide rapid pain relief, enhance quality of life, reduce the duration of treatment, and demonstrate sustained benefits over the long term.

Guidelines emphasize a conservative, multimodal approach. Initial management includes patient education, reassurance, and encouragement to remain active (7). Pharmacological options such as non-steroidal anti-inflammatory drugs (NSAIDs) may be used for symptom relief, while imaging is generally reserved for red-flag presentations. For persistent cases, physical therapy, exercise programs, and cognitive-behavioral interventions are recommended (8).

The effectiveness of conventional physical therapy (CPT) modalities in pain reduction remains a matter of scholarly debate; nevertheless, evidence indicates that such interventions may yield outcomes superior to placebo in certain clinical scenarios (9). Transcutaneous electrical nerve stimulation (TENS), one of the most widely used modalities, has demonstrated equivocal efficacy in acute pain conditions; however, randomized controlled trials suggest that TENS confers short-term analgesic benefits in patients with chronic LBP (10,11). In addition, superficial heat therapy, such as hot pack (HP) application, has been shown to provide temporary symptom relief in individuals with LBP (12).

In recent years, extracorporeal shock wave therapy (ESWT) has been increasingly employed in the management of non-radicular LBP (13,14). The therapeutic effects of ESWT in LBP are thought to arise from multiple mechanisms, including anti-inflammatory and analgesic properties, enhanced local blood circulation, modulation of central sensitization, and direct tissue-level effects. ESWT produces

analgesic effects by inducing biochemical alterations in nerve fibers and decreasing soft-tissue inflammation (15). Moreover, ESWT has been reported to promote revascularization and to activate or enhance the repair processes of connective tissues, such as tendons and bones, thereby contributing to pain reduction, functional recovery, and better overall quality of life (13,16). Furthermore, while ESWT has demonstrated effectiveness in the management of LBP, conventional physiotherapeutic approaches-such as TENS, hot pack application, and therapeutic ultrasound-continue to be widely employed. However, the existing body of literature directly comparing the efficacy of ESWT with these traditional modalities remains limited (16-19). The objective of this study is to evaluate the therapeutic effects of radial ESWT on pain intensity, disability, and depressive symptoms in individuals with nonradicular LBP.

MATERIAL AND METHODS

A total of 75 patients diagnosed with chronic nonradicular LBP at the department of physical medicine and rehabilitation outpatient clinic between September 2024 and March 2025 were enrolled in a prospective, randomized, sham-controlled, single-blind study.

The ethics committee of Ankara Bilkent City Hospital approved the study on July 10, 2024 (reference number: TABED-2-24-246). Written informed consent was obtained from all participants. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The inclusion criteria were as follows: Male or female patients aged 18-60, nonspecific, nonradicular (axial) chronic LBP diagnosis, LBP that persists for more than three months without a specific cause; VAS score greater than 3 points; voluntarily participating in the study and giving informed consent. The

exclusion criteria were individuals with a diagnosis of spondylolisthesis, spondylolysis, spinal tumors, intervertebral disc infections, severe osteoporosis, or lumbar vertebral fractures, and patients with a history of prior spine surgery, currently using anti-inflammatory drugs or analgesics in the last four weeks, local skin infection or damage at the treatment site, inflammatory rheumatic diseases, pregnancy, and concomitant mental diseases.

Following the Consolidated Standards of Reporting Trials (CONSORT) guidelines for registered randomized clinical trials, the patient flow over the entire study period is shown in Figure 1. Sixty-nine patients who met the inclusion criteria were randomized into two groups: group 1: rESWT (n=35); group 2: sham ESWT (n=34), using a computer random number generator (www.random.com). Group 1 received rESWT combined with an exercise program, whereas Group 2 received sham ESWT combined with the same exercise program. CPT (HP and TENS) was applied to both groups. Demographic data for participants, including age, gender, education, occupation, smoking status, and pain duration, were recorded. The same physician conducted all assessments and questionnaires. One physiotherapist performed all treatment protocols and exercise programs.

Pain intensity was assessed using the Visual Analog Scale (VAS), a 10-cm scale ranging from 0 (no pain) to 10 (worst imaginable pain), with higher scores indicating greater pain severity (20). Disability was evaluated using the Oswestry Disability Index (ODI), a validated questionnaire assessing the impact of low back pain on daily activities, with higher scores reflecting greater disability (21). Anxiety and depressive symptoms were assessed using the Hospital Anxiety and Depression Scale (HADS), which consists of two 7-item subscales for anxiety (HADS-A) and depression (HADS-D), with higher scores indicating greater symptom severity (22).

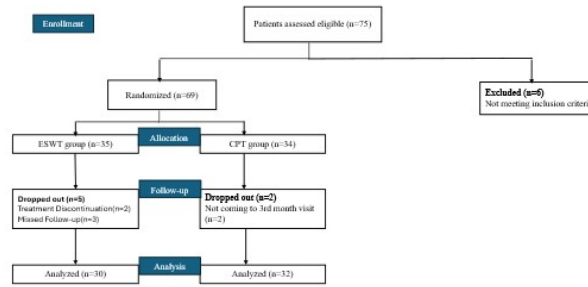


Figure 1. CONSORT flow chart of study participants

Table 1. Demographic data and some clinical features of all patients and patient groups

	All patients	Sham group (n=32)	ESWT group (n=30)	P-value
Age (mean±SD)	46.4±10.3	47.0±10.1	45.7±10.7	0.616*
Gender (n/%)				0.799†
Female	38 (61.3)	19 (59.4)	19 (63.3)	
Male	24 (38.7)	13 (40.6)	11 (36.7)	
Education (n/%)				
Primary school	7 (11.3)	3 (9.4)	4 (13.3)	0.832†
Highschool	24 (38.7)	12 (37.5)	12 (40.0)	
University	31 (50.0)	17 (53.1)	14 (46.7)	
Occupation (n/%)				0.789†
Working	41 (66.1)	22 (68.8)	19 (63.3)	
Non-working	21 (33.9)	10 (31.2)	11 (36.7)	
Smoking (n/%)				0.324‡
Smoker	13 (21.0)	5 (15.6)	8 (26.7)	
Non-smoker	39 (62.9)	20 (62.5)	19 (63.3)	
Ex-smoker	10 (16.1)	7 (21.9)	3 (10.0)	
Duration of pain (months) (median: IQR)	17.0 (11.5-24.0)	20.0 (8.0-24.0)	14.0 (12.0-24.0)	
Side of pain (n/%)				0.755‡
Right	21 (33.9)	12 (37.5)	9 (30.0)	
Left	24 (38.7)	11 (34.4)	13 (43.3)	
Bilateral	17 (27.4)	9 (28.1)	8 (26.7)	
Have you received any treatment previously?				0.322†
Yes	29 (46.8)	17 (53.1)	18 (60.0)	
No	33 (53.2)	15 (46.9)	12 (40.0)	

* Independent sample t-test, † Fisher's exact test, ‡ Pearson Chi-square test, SD: Standard deviation, ESWT: Extracorporeal shock wave treatment

Significant improvement was observed in VAS, ODI, and HADS in the ESWT group after treatment and at the 1st month after treatment compared with pre-treatment (all $p < 0.001$). In intra-group comparisons within the sham ESWT group, only the VAS and HAD scores were significantly lower post-treatment and at the 1-month follow-up than at baseline ($p < 0.001$). Whereas the ODI score showed no significant difference immediately after treatment but was significantly lower at the first month compared to baseline in the sham ESWT group ($p > 0.05$).

Inter-group comparisons revealed that VAS baseline ($p = 0.199$), after treatment ($p = 0.206$), and

at the first month ($p = 0.129$) and HADS anxiety scores baseline ($p = 0.574$), after treatment ($p = 0.383$) and at the first month ($p = 0.528$), HADS depression scores baseline ($p = 0.255$), after treatment ($p = 0.479$), and at the first month ($p = 0.882$) were comparable at. ODI scores were also similar between groups at baseline ($p = 0.543$) and at the first month ($p = 0.101$); however, the ESWT group showed significantly lower ODI scores immediately after treatment compared to the sham group ($p = 0.011$). Table 2 summarizes the VAS, ODI, and HADS scores along with within-group and between-group comparisons. Figures 2 and 3 illustrate the changes in VAS and ODI scores over time.

Table 2. Visual analog scale, Oswestry disability index, and hospital anxiety and depression scale scores of the groups

	Sham group (n=32)	ESWT group (n=30)	P-value
	Median (25th-75th percentiles)		
VAS-before treatment	7.0 (5.0-8.0)	7.0 (6.8-8.0)	0.199 [†]
VAS-after treatment	5.0 (4.0-6.0)	5.0 (4.0-5.0)	0.206 [†]
P‡	<0.001*	<0.001*	
VAS-1st month	4.5 (3.0-5.0)	3.5 (2.8-5.0)	0.129 [†]
P‡	<0.001*	<0.001*	
ODI-before treatment	27.0 (22.0-32.0)	29.0 (23.5-32.5)	0.543 [†]
ODI-after treatment	26.0 (20.0-32.0)	20.0 (16.0-24.0)	0.011[†]
P	0.113*	<0.001*	
ODI-1st month	24.0 (18.5-32.8)	22.0 (12.0-26.5)	0.101 [†]
P‡	0.010*	<0.001*	
HADS-anxiety-before treatment	7.0 (5.3-8.0)	7.0 (5.8-10.3)	0.574 [†]
HADS-anxiety-after treatment	6.0 (4.0-7.8)	5.0 (3.8-8.0)	0.383 [†]
P‡	0.013*	<0.001*	
HADS-anxiety-1 st month	6.5 (3.0-8.0)	5.0 (3.0-8.0)	0.528 [†]
P‡	0.002*	<0.001*	
HADS-depression-before treatment	5.0 (3.0-7.0)	6.0 (4.8-8.0)	0.255 [†]
HADS-depression-after treatment	4.5 (2.0-6.8)	5.0 (3.0-7.0)	0.479 [†]
P‡	0.001*	<0.001*	
HADS-depression-1 st month	4.5 (2.3-7.8)	5.0 (2.8-7.0)	0.882 [†]
P‡	0.030*	<0.001*	

* Wilcoxon signed-rank test, † Mann-Whitney U test, ‡ p-values show the results of the Wilcoxon signed-rank test compared to the above values, with the values before treatment; VAS: Visual analog scale, ODI: Oswestry disability index, HADS: Hospital Anxiety and Depression Scale

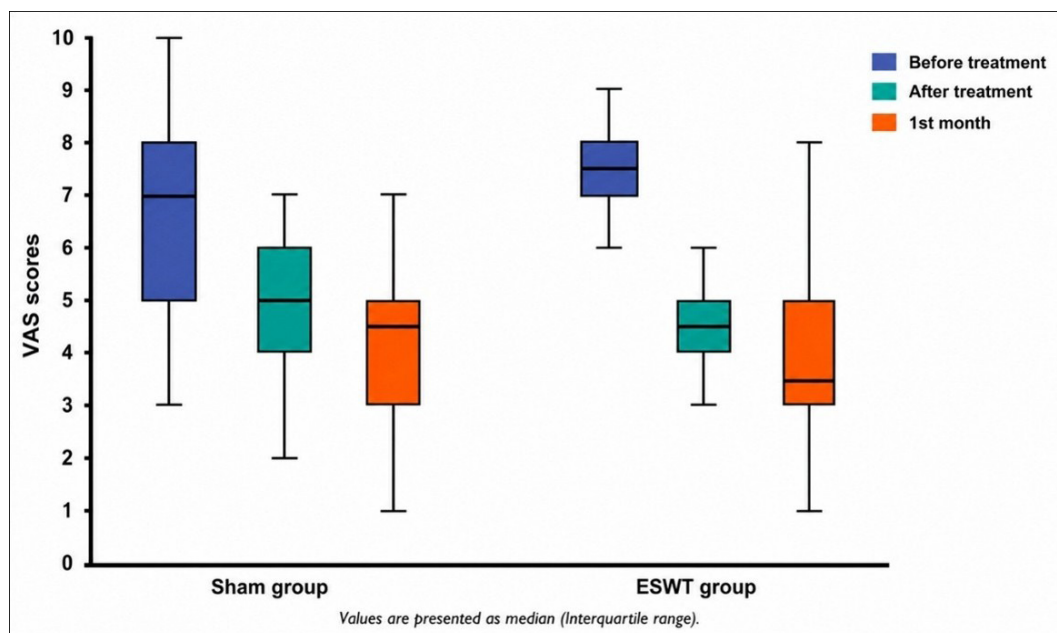


Figure 2. The box plot of visual analog scale scores for the sham and ESWT groups during follow-up
ESWT: Extracorporeal shock wave treatment

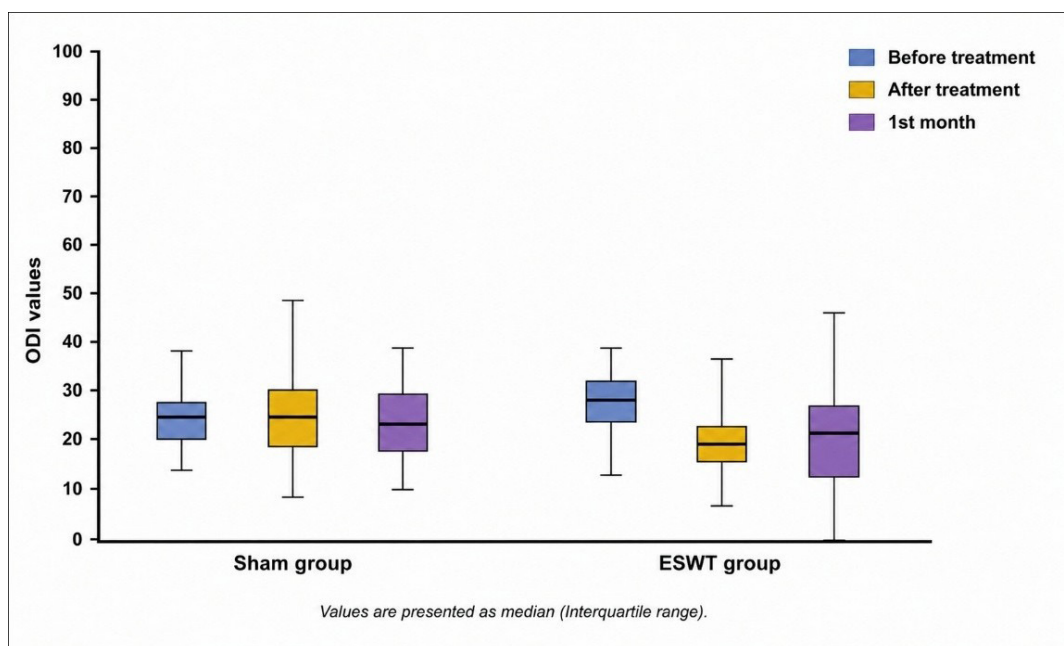


Figure 3. The box plot of Oswestry disability index scores for the sham and ESWT groups during follow-up
ESWT: Extracorporeal shock wave treatment

When comparing the magnitude of change in the outcome scales from baseline (pre-treatment), the ESWT group showed a significantly greater improvement in VAS scores both post-treatment ($p=0.002$) and at the 1-month follow-up ($p=0.035$) and ODI scores both post-treatment ($p<0.001$) and at the 1-month follow-up ($p=0.014$). The improvement in the HADS-anxiety score was also greater in the ESWT group immediately post-treatment ($p=0.036$).

However, the magnitude improvement in the HADS-anxiety score at the 1-month follow-up ($p=0.184$), and the improvement in the HADS-depression score both post-treatment ($p=0.994$) and at 1-month ($p=0.177$), were similar between the groups. These results are summarized in Table 3.

Table 3. Comparison of the changes in outcome scores from baseline after treatment and at 1st month of the treatment

Change from baseline scores	Sham group (n=32)	ESWT group (n=30)	P-value
	Mean $\pm$ SD or Median (25 th -75 th percentiles)		
VAS-after treatment	1.8 $\pm$ 1.4	2.9 $\pm$ 1.3	0.002*
VAS-1 st month	2.3 $\pm$ 1.9	3.3 $\pm$ 1.7	0.035*
ODI-after treatment	2.0 (-2.0-3.5)	6.5 (4.0-12.0)	<0.001†
ODI-1st month	0.0 (0.0-5.5)	8.0 (0.0-12.5)	0.014†
HADS-anxiety-after treatment	1.0 (-0.8-2.0)	1.5 (1.0-2.3)	0.036†
HADS-anxiety-1 st month	1.0 (0.0-3.0)	1.0 (1.0-2.3)	0.184†
HADS-depression-after treatment	1.0 (0.3-2.0)	1.0 (0.3-2.0)	0.994†
HADS-depression-1 st month	1.0 (0.0-1.8)	1.0 (0.8-2.0)	0.177†

* Independent samples t-test, † Mann-Whitney U test, VAS: Visual analog scale, ODI: Oswestry disability index, HADS: Hospital Anxiety and Depression Scale

DISCUSSION

In this study, radial ESWT was found to be superior to CPT in patients with chronic non-specific and non-radi-
cular LBP, as indicated by VAS, HADS, and ODI scores. Our findings indicate that ESWT was associated with significant short-term improvements in pain, disability, and psychological symptoms, whereas sham treatment failed to provide comparable benefits except for a delayed reduction in disability.

The consistent within-group improvements in VAS and ODI in the ESWT group indicate that ESWT had a beneficial effect on both pain intensity and functional impairment. The additional finding that the between-group difference in ODI was significant immediately post-tre-

atment suggests that ESWT produced a more rapid functional benefit compared to sham, though this superiority diminished over time.

These results align well with prior randomized controlled trials and meta-analyses supporting ESWT for chronic LBP and related conditions. In a previous study, Han et al. observed significant improvements in VAS, ODI, and depression in patients receiving ESWT versus baseline values(17). In a meta-analysis of 12 RCTs including 632 patients, Liu et al. found that ESWT produced significantly greater pain relief and greater improvements in dysfunction than control interventions (23). Wu et al. similarly reported that ESWT had significant effects on VAS and ODI at post-treatment and at the 3-month

follow-up relative to controls (24). Notably, ESWT demonstrated superiority over sham treatment in functional outcomes immediately after the intervention, although group differences in pain and psychological measures were not evident. These results, which align with previous evidence, suggest that ESWT may exert beneficial effects on musculoskeletal pain and function through both mechanical and neuromodulatory mechanisms, while also highlighting the potential role of placebo responses in subjective outcomes. In particular, the fact that the ESWT group showed a statistically significantly lower ODI immediately post-treatment than the sham group, while baseline and 1-month ODI were similar between groups, suggests a more rapid functional benefit from ESWT.

In our trial, we used radial ESWT (rESWT), which delivers lower peak pressures over a wider area than focused ESWT (fESWT). This distinction is clinically relevant, as different ESWT modalities may induce heterogeneous biological responses. Previous evidence supports both forms in the treatment of LBP, though most studies have used rESWT. For example, Walewicz et al. applied rESWT in combination with stabilization training and demonstrated significant improvements in pain and disability compared to sham stimulation (25). Similarly, Ejaz et al. used rESWT and found superior reductions in pain and disability relative to Maitland mobilization in mechanical LBP (26). These findings align with our results, confirming that rESWT is an effective, non-invasive option for musculoskeletal rehabilitation. By contrast, Nedelka et al. employed focused ESWT (fESWT) in patients with lumbar facet joint syndrome and reported sustained reductions in VAS and ODI up to 12 months (27). Likewise, Chen et al. compared different ESWT regimens (energy settings and session numbers), showing that low-intensity fESWT with more sessions resulted in superior short-term pain and disability improvement compared to higher-intensity fESWT with fewer sessions (28). These fESWT studies suggest greater durability, although the biological ef-

fects and treatment targets differ from those of radial applications.

Importantly, Liu et al. included mental health outcomes and confirmed that ESWT improves both pain and disability, with modest additional benefit in anxiety/depression domains (23). Wu et al. extended this evidence, demonstrating that ESWT improves pain, functional impairment, and psychological outcomes relative to controls (24). It is noteworthy that, in intra-group comparisons of sham ESWT, HADS outcomes also improved significantly, further supporting a non-specific psychosocial component. Sun et al. also documented improvements across all VAS, ODI, and HADS metrics in the ESWT arm, though not always using a sham comparator (28). Our trial's sham group helps clarify that psychological improvements may not be unique to ESWT per se.

Dosage is another critical parameter. In LBP trials, the number of shock impulses per session typically ranges from 2000 to 4000, with energy flux densities of 0.08-0.25 mJ/mm², and weekly applications for 3-6 sessions. Radial protocols, including ours, often use higher shock counts with lower penetration depth, making them suitable for treating superficial myofascial sources of pain. Focused ESWT studies, in contrast, tend to employ lower shock counts but higher energy densities, aiming at deeper nociceptive generators such as facet joints or paraspinal structures.

Although the precise biological mechanisms of ESWT in spinal pain are not fully elucidated, several plausible pathways have been proposed: anti-inflammatory and tissue-modulation effects, analgesic/neuromodulatory effects, improved tissue perfusion and clearance of metabolites, mechanical stimulation, and mechanotransduction. In our study, the relatively rapid onset of functional benefit (ODI) immediately post-treatment may reflect early analgesic or neuromodulatory effects rather than slower structural remodeling. The subsequent convergence of groups over time suggests that non-ESWT factors (e.g., rehabilitation, spontane-

ous recovery) play a role, or that ESWT's incremental advantage may diminish with time unless sustained or repeated.

Taken together, these findings suggest that rESWT is particularly effective for short-term pain relief and functional gains, as observed in our trial, whereas fESWT may provide longer-lasting benefits in specific pathologies, such as facet syndrome. The question of optimal dosage and modality selection remains open. Current evidence supports tailoring ESWT parameters based on the pain generator (myofascial vs. joint-related), desired tissue depth, and patient tolerance. Our findings add to the evidence base for radial protocols, supporting their efficacy in LBP management while highlighting the need for future head-to-head trials comparing radial and focused forms, and for exploring optimal session numbers, energy levels, and long-term sustainability.

Study Limitations

This study has several limitations that should be acknowledged. First, the follow-up period was limited to one month, which restricts the ability to assess the durability of treatment effects or to capture differences that may emerge or diminish beyond this timeframe. Second, the relatively modest sample size may have reduced the statistical power to detect sub-effects, particularly in psychological domains such as anxiety and depression, where between-group differences might require larger cohorts to reach significance. Third, the generalizability of our findings is constrained by the specific characteristics of the study population and the ESWT protocol employed, including dose, energy parameters, and concomitant therapies, which may limit applicability to broader clinical contexts. Additionally, although a sham control was used, potential placebo and expectation effects cannot be entirely excluded, as subtle cues or patient perceptions may have influenced outcomes. Another limitation is the

absence of mechanistic biomarkers or imaging data, which precludes a deeper understanding of the biological processes underlying the observed improvements. Finally, the study did not include longer-term repeated-dose or booster sessions, leaving it unclear whether sustained or enhanced benefits might be achieved with ongoing treatment.

Future studies should consider longer follow-up periods (e.g., 3, 6, and 12 months) to assess durability and potential late divergence of groups, and larger sample sizes to achieve adequate power for psychological and subgroup analyses. Future studies should optimize ESWT protocols by evaluating dose-response relationships and treatment parameters, including energy flux, number of shocks, and session frequency. Mechanistic outcomes, such as imaging, biomarkers, nerve conduction studies, and ultrasound elastography, may help clarify tissue-level effects. The potential benefits of combining ESWT with exercise, manual therapy, or cognitive approaches should also be investigated. Finally, cost-effectiveness and patient-reported outcomes should be considered to support its broader clinical implementation.

CONCLUSION

Clinically, our findings support rESWT as a promising adjunctive treatment for improving pain and functional impairment in patients with chronic nonradicular LBP in the short term. The early advantage in functional gain (ODI) suggests that ESWT may accelerate recovery, which could be beneficial in contexts where rapid functional improvement matters (e.g., return to work). The modest but not sustained superiority in psychological outcomes indicates that ESWT should likely be integrated with multimodal interventions (e.g., cognitive-behavioral therapy, exercise) rather than relied on as a standalone mood therapy.

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Author Contributions

Protocol/project development: EEB, FS, KÇ, BES

Data collection and management: EEB, FS, KÇ, BES

Data analysis: EEB, FS, KÇ, BES

Manuscript writing/editing: EEB, FS, KÇ, BES

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