



Effects of High Intensity Laser Therapy on the Morphology of Subacute Herniated Lumbar Disc

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Abstract:

Background: lumbar disc herniation (LDH) is one of the most frequent causes of low back pain as well as lower extremity radicular syndrome. **Aim:** to examine the impacts of High Intensity Laser Therapy (HILT) on the morphology of subacute lumbar disc herniation. **Patients and Methods** Sixty patients of both sexes with subacute lumbar disc herniation with back and leg pain, aged from 20 to 50 took-part in this study. patients were randomized into two equivalent groups. **Group A control group:** treated by medication only. **Group B study group:** treated by medication and 10 sessions of high intensity laser three times a week over the back on the level of herniated disc. assessment was done before and after the treatment using MRI scans to measure the morphological changes of the herniated disc for the two groups. A visual analogue scale was utilized to evaluate pain level and an inclinometer was used to measure the change of angle of straight leg raising test (SLR). **Results:** revealed that within study group B, there were significant ($P<0.05$) decrease in anteroposterior disc diameter in axial view and in pain level and increase in the angle of SLR post treatment compared to pre-treatment. while there were no significant differences ($P>0.05$) within group A. Between groups, at after-treatment, there were significant difference ($P<0.05$) in transverse diameter in axial view, anteroposterior disc diameter in axial view, pain level and the angle of SLR, in group B. There was significantly ($P<0.05$) positive strong correlation between anteroposterior disc diameter with pain level and negative strong correlation with the angle of straight leg raising scale in patients diagnosed as sub-acute lumbar disc herniation with back and leg pain.

Conclusion: HILT is an efficient noninvasive physiotherapy modality in reducing disc diameter and pain in patients with subacute lumbar disc herniation in relatively short period of time.

Keywords: High Intensity Laser Therapy, Lumbar Disc Herniation, Disc morphology, MRI.

1. Introduction

Lumbar disc herniation (LDH) is a prevalent source of acute, chronic, and recurrent low back pain (LBP), primarily affecting the L4-L5 and L5-S1 levels in 98% of cases. It typically develops in the weakest part of the disc, the posterolateral side, where the annulus fibrosus is thinner and lacks structural support from the anterior or posterior longitudinal ligaments. The most common age group for lumbar disc herniation (LDH) is between 30 and 50 years, with a higher incidence in men. However, it can occur at any age.¹

Lumbar disc herniation (LDH) occurs when disc material bulges out from its normal location within the intervertebral disc space. One to five percent of the population experiences sciatica symptoms every year as a result of mechanical compression as well as chemical irritation of the nearby nerve roots.²

Nerves can be stretched and deformed by mechanical compression, which may also constrict microcirculation, leading to ischemia and radicular symptoms. Additionally, a herniated disc triggers an extensive inflammatory reaction necessary for resorbing the herniated material, but this inflammation can chemically irritate the nerve root, resulting in radicular symptoms.³

Lumbar disc herniation is a prevalent condition that can significantly reduce functional ability, leading to disability and a poor quality of life. According to clinical outcomes and patient preferences a customized treatment approach may include either conservative or surgical procedures. Lumbar disc herniation treatment is essential for pain management, prevention of recurrence, chronic pain and disability, and facilitating a quicker return to work. Most patients prefer conservative treatments for lumbar disc herniation rather than surgical procedures due to the lower risk of complication.⁴

Disc regression significantly improved symptomatic outcomes for individuals with LDH who were conservatively treated, as reported by **Kesikburun et al., 2019**⁵. In patients with acute lower back pain and leg pain due to LDH, **Unlu et al., 2008**⁶ found that MRI scans showed a reduction in disc herniation size following treatment with traction, ultrasound, or low-power laser (LPL) therapies.

Laser therapy is often used in physical therapy to alleviate pain associated with musculoskeletal disorders, accelerate wound healing, and repair damaged tissues. Its analgesic effects are linked to the modulation of the inflammatory process, the production of endogenous opioid peptides (β -endorphins), and the reduction of nerve conduction velocity, especially at higher potencies.⁷

The emission power of laser therapeutic devices determines their classification: class IIb, which refers to low-level laser therapy (LLLT), and class IV, which refers to high-intensity laser therapy (HILT).⁸

Compared to LLLT, high intensity laser therapy has obvious advantages as it allows for the delivery of higher energy over time. By increasing the amount of energy absorbed in deep tissues, HILT produces thermal effects in addition to the biological impacts of LLLT. HILT's infrared spectra wavelengths allow it to penetrate deeper tissues, increasing the amount of energy delivered to these areas (averaging depths of 10-12 cm).⁹

HILT is a relatively new, non-invasive, painless procedure, characterized by its photothermal and photomechanical effect. Some of the laser light energy can be converted into mechanical forces that act on the tissues and cells being treated.¹⁰

Mechanical forces can physically alter the treated cells and tissues, leading to changes in size and structure. These changes can stimulate cellular metabolism, proliferation, differentiation, and ultimately tissue regeneration.¹¹

2. MATERIALS AND METHODS

2.1 Design

This study used a pre-test-post-test experimental design. The research ethics committee of the Faculty of Physical Therapy approved the study before it began (NO: P.T.REC/012/002868) in accordance with institutional review board guidelines. This study was conducted during the period from June 2021 to December 2023 in the outpatient clinic of Cleopatra Hospital, Cairo, Egypt.

2.2 Randomization

Patients were randomized into two groups.

2.3 Patients

Sixty patients their age range from 20 to 50 diagnosed with subacute lumbar disc herniation with back and leg pain were randomized into two equal groups. Group A: It involved thirty patients from both sexes treated by medication only. Group B: It involved thirty patients of both sexes treated by high intensity laser (Hiro TT). Informed consent was taken from each individual after clarifying the scope and aim of the research and ensuring them of their right to decline at any time and of the privacy of any information obtained (Appendix I). All data were coded to ensure privacy.

2.4 Outcome Measures and Assessment Procedures

2.4.1 Pain:

A visual analogue scale (VAS) was used to evaluate degree of lumbosacral portion pain and lower limb radiation pain before and after treatment.

A VAS consists of 10 cm long line and, participants were requested to indicate the intensity of their pain on a VAS, from 0 (no pain) on the extreme left to 10 (the worst possible agony) on the extreme right.

2.4.2 Range of motion:

Assessment of a straight leg raise (SLR) range of motion was conducted using the hand-held inclinometer. As a neural tension test, it can help determine whether a space-occupying lesion, such as a herniated lumbar disc, is affecting neural tissue. This is a frequent neurological evaluation of the lower extremities.

Patients were asked to lie supine with their legs extended to evaluate sciatica. The examiner uses one hand to extend the patient's affected knee while the other for raising the ankle. This process is repeated slowly until the patient reports radiation pain in their lower extremities, at this point the examiner records the angle using the inclinometer.¹²

2.4.3 Lumbar disc herniation:

Magnetic Resonance Imaging (MRI): To confirm the possibility of LDH, it is considered the gold standard. In diagnosing of herniated discs, it is the most sensitive study available, owing to its significant capacity for visualizing soft tissues; the accuracy rate is 97%.¹³

Measuring anteroposterior and transverse diameter in axial view:

Using axial view imaging, transverse (Figure 1) and anteroposterior (Figure 2) diameters of the herniation were measured to calculate the difference between before and after treatment.

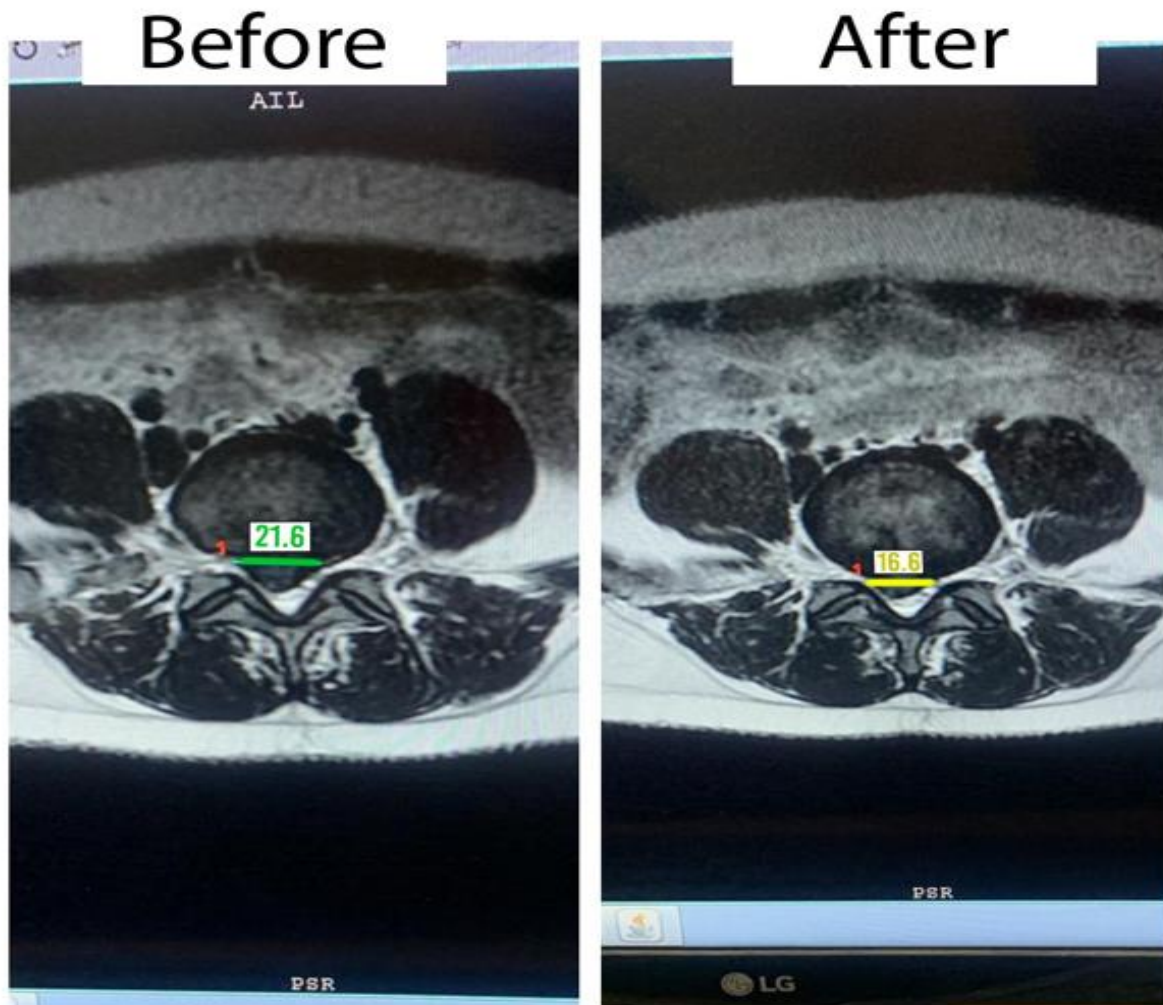


Figure 1: measurement of transverse diameter(mediolateral) before and after treatment in axial view.



Figure 2: Measuring anteroposterior diameter (vertical) before and after treatment in axial view.

2.5 Treatment Procedures

2.5.1 High power laser therapy

Pulsed Nd:YAG Laser produced by, **Hilterapia® HIROTT (ASA)** (ASA laser, Arcugnano, Vicenza, Italy). Among the features offered by the device were pulsed emission (1,064 nm), a short duration (120-150 μ s), a low frequency (10-40 Hz), a high fluency/energy density (510-1,780 mJ/cm²), and a very high peak power (3 kW)."Each protocol is graphically supported by sequences of images and videos depicting the target areas and the location of the pathology that requires treatment. HIRO TT allows the treatment to be fully customized according to the morphometric characteristics of the patients and the color of their skin, making it possible to calibrate the energy and optimize treatment times, maintaining high standards of safety and efficacy. Use sciatica program and connect the 5mm hand piece. The patient was positioned prone, with the handpiece in contact and angled perpendicular to the treatment area. Scanning was conducted transversely and longitudinally over the lower back at the level of herniation. The program was divided into three phases, with each phase further divided into three subphases.

In the first phase, which was divided into three sub-phases with doses of 510, 970, and 1070 mJ/cm², a total energy of 1.248 J was applied. This phase was performed using fast manual scanning

During the middle phase, treatment was applied over the paravertebral trigger points. A total of 25 J was delivered, with fluences of 360, 510, and 610 mJ/cm², and a duration of 6 seconds at each point.

The final phase was identical to the first phase but performed with slow manual scanning.

A total of 2,500 J was delivered across the three phases, with the whole application process taking approximately fifteen minutes. HILT was applied for a total of 10 treatment sessions (three sessions per week).

2.6 Sample Size Calculation

The G*power software 3.1.9 (G* power program version 3.1, Heinrich-Heine-University, Düsseldorf, Germany) was used for calculating sample size for this study. According to the results of the F tests (MANOVA: Special effects and interactions), the power (1- β error probability) = 0.95, the Pillai V = 0.3443709, and the effect size f^2 (V) = 0.208. The sample size was calculated using two independent groups comparison for 4 major variable outcomes. Acceptable sample size of sixty for this study (thirty patients per group required as a minimum).

Statistical analysis

Assumptions of normality as well as homogeneity of variance were tested on the data. The data was found to follow a normal distribution ($P > 0.05$) after the removal outliers identified by box and whiskers plots, according to a normality test of data utilizing the Shapiro-Wilk test. Furthermore, no significant difference was found ($P > 0.05$) when Levene's test for homogeneity of variance was applied. The data follows a normal distribution and parametric analysis was used.

Software developed by SPSS, Inc. of Chicago, IL, USA, version 25 for Windows, was used to do the statistical analysis. The data is presented as the mean with standard deviation for the following quantitative variables: patient's age, pain level as measured by a VAS, angle of SLR, transverse diameter in axial view, and anteroposterior disc diameter in axial view. For the sex variable, qualitative data is presented as a frequency as well as percentage. The age variable was compared between Group A and Group B using unpaired t-test. The sex variable was compared between Group A and Group B using a chi-square test. Mixed design 2×2 Multivariate analysis of variance (MANOVA) test, 1st independent variable is the tested groups (group A vs. group B) and the 2nd independent variable is the measurement periods (before-treatment vs. after treatment). The outcome dependent variables were the primary factors of kyphosis, which included the VAS, the angle of SLR, the transverse disc diameter in axial view, as well as the anteroposterior disc diameter in axial view. When the MANOVA test found a statistically significant F value for one of the investigated variables, we utilized the Bonferroni adjustment test to compare the two sets of data within and across the groups. There was a significant degree of probability ($P < 0.05$) in all statistical studies.

RESULTS

In this study, an overall of 60 patients diagnosed as sub-acute lumbar disc herniation with back and leg pain were randomly distributed into 2 equal groups (30 patients / group). The findings of

clinical general demographic data for patients (Table 1) revealed that there were no significant differences ($P>0.05$) among group A and group B in patients age ($P=0.899$) and gender ($P=0.598$).

Table 1. Patients' general characteristics in both groups

Items	Groups (Mean $\pm$ SD)		P-value
	Group A (n=30)	Group B (n=30)	
Age (year)	31.10 $\pm$ 5.40	31.38 $\pm$ 7.19	0.899
Gender (male: female)	17 (56.70%): 13 (43.30%)	19 (63.30%): 11 (36.70%)	0.598

Quantitative variable data (age) are expressed as mean $\pm$ standard deviation and compared statistically by independent t-test

Qualitative variable data (gender) are expressed as frequency (percentage) and compared statistically by Chi-square test

P-value: probability value

P-value > 0.05 : non-significant

Statistical multiple pairwise comparison tests for main variable outcomes within each group (Table 2) revealed that there were significant ($P<0.05$) decrease within group B in pain level VAS ($P=0.0001$) and anteroposterior disc diameter in axial view ($P=0.019$) at after-treatment in comparison with before-treatment. But, in group A, there were insignificant ($P>0.05$) decrease in pain level ($P=0.669$) and anteroposterior disc diameter in axial view ($P=0.952$) at after-treatment in comparison with before-treatment. Moreover, there was a significant ($P<0.05$) increase within group B in the angle of SLR ($P=0.0001$) at after-treatment in comparison with before-treatment. But, insignificant ($P>0.05$) increase in the angle of SLR ($P=0.445$) at after-treatment in comparison with before-treatment within group A. There were no significant differences ($P>0.05$) between pre and post treatment in transverse diameter in axial view within group A ($P=0.441$) and group B ($P=0.264$). The patients in group B showed improved percentages of pain level (54.06%), angle of SLR (92.38%), transverse diameter in axial view (10.02%), and anteroposterior disc diameter in axial view (23.53%) than patients in Group A (4.05, 12.70, 9.21, and 0.76%, respectively).

No statistically significant differences ($P>0.05$) were found between groups A and B pretreatment in pain level ($P=0.669$), the angle of SLR ($P=0.445$), transverse diameter in axial view ($P=0.441$), and anteroposterior disc diameter in axial view ($P=0.952$) when comparing the two groups' main variable outcomes using statistical multiple pairwise comparison tests (Table 2). At after-treatment, there were significant difference ($P<0.05$) in pain level ($P=0.0001$), angle of SLR ($P=0.0001$), transverse diameter in axial view ($P=0.0001$), and anteroposterior disc diameter in axial view ($P=0.0001$). Moreover, these significant differences at after-treatment in pain level, angle of SLR, transverse diameter in axial view, and anteroposterior disc diameter in axial view are favorable for patients diagnosed as sub-acute LDH with back and leg pain in group B than those in group A.

Table 2: Within and between groups comparison for main variable outcomes

Variables	Items	Groups (Mean $\pm$ SD)		Change	P-value
		Group A (n=30)	Group B (n=30)		
Pain level (Visual analogue scale)	Before-treatment	7.40 $\pm$ 1.17	7.88 $\pm$ 1.58	0.48	0.408
	After-treatment	7.10 $\pm$ 1.91	3.62 $\pm$ 1.52	3.48	0.0001*

	Change (MD)	0.30	4.26		
	95% CI	4.05%	54.06%		
	Improvement %	-1.09 – 1.69	3.40 – 5.13		
	P-value	0.669	0.0001*		
Angle of straight leg raising	Before-treatment	31.50 ±8.18	27.69 ±10.02	3.80	0.383
	After-treatment	35.50 ±14.99	53.27 ±12.80	17.76	0.0001*
	Change (MD)	4.00	25.57		
	95% CI	12.70%	92.38%		
	Improvement %	-6.39 – 14.39	19.12 – 32.02		
	P-value	0.445	0.0001*		
Transverse diameter in axial view	Before-treatment	18.68 ±5.95	15.47 ±4.59	3.21	0.087
	After-treatment	20.40 ±6.54	13.92 ±4.18	6.48	0.0001*
	Change (MD)	1.72	1.55		
	95% CI	9.21%	10.02%		
	Improvement %	-2.70 – 6.14	-1.19 – 4.29		
	P-value	0.441	0.264		
Anteroposterior disc diameter in axial view	Before-treatment	7.94 ±2.93	6.29 ±1.83	1.64	0.051
	After-treatment	7.88 ±3.62	4.81 ±1.49	3.06	0.0001*
	Change (MD)	0.060	1.48		
	95% CI	0.76%	23.53%		
	Improvement %	-1.92 – 2.04	0.25 – 2.71		
	P-value	0.952	0.019*		

Group A: subjects were treated by medication only; Group B: subjects were treated by high intensity laser
 Data are expressed as mean ±standard deviation MD: Mean difference CI: confidence interval
 P-value: probability value * Significant (P<0.05)

Bi-variate Pearson's correlation coefficient was computed between anteroposterior disc diameter with pain level and angle of SLR in group B for patients diagnosed as sub-acute LDH with back and leg pain (Table 3). The result of this correlational analysis revealed that there was significantly (P<0.05) positive strong correlation between anteroposterior disc diameter with pain level (r=0.761; P=0.0001) and negative strong correlation with the angle of SLR (r= -0.690; P=0.0001). This positive and negative correlation means that change in the anteroposterior disc diameter is consistent with change in the level of pain (visual analogue scale) and the angle of SLR. The direction of the relation between pain level and anteroposterior disc diameter is positive, where when the anteroposterior disc diameter increased the pain level (VAS) increased in patients suffering from sub-acute LDH with back and leg pain. Moreover, the direction of the relation between the angle of SLR and the anteroposterior disc diameter is negative, where when the anteroposterior disc diameter increased the angle of SLR decreased in patients suffering from sub-acute LDH with back and leg pain.

Table 3. Correlation between anteroposterior disc diameter with pain level (visual analogue) and the angle of straight leg raising in group B

Items	r-value	P-value
Pain level	0.761	0.0001*
Angle of straight leg raising	-0.690	0.0001*
r: Pearson correlation coefficient value	P-value: probability value	*Significant: P>0.05

Discussion

There is a significant social cost associated with intervertebral disc disease due to the high work disability and healthcare expenses. lumbar disc herniation (LDH) It is one of the leading causes of low back pain and extremity radicular syndrome. The management of LDH is essential for controlling pain, Preventing the development of disability, recurrence, and chronic pain, and speeding the return to work.^{14&15}

Based on the results of this study, conservative treatment of herniated discs may lead to regression of the herniated disc, improved clinical outcomes, and a quicker return to work.

This study can be considered a pioneer study in the field of physical therapy provides the first data on the effects of HILT on the morphology of the herniated disc in patients with Sub-acute LDH.

The selection of cases in the subacute phase was intended to exclude the effects of spontaneous regression, as it has been demonstrated that it takes a minimum of six months for a prolapsed disc to be naturally absorbed.¹⁶

Current literature suggests that the morphology of lumbar disc herniation may change over time without surgery. The findings revealed that most patients in the study group experienced a significant decrease in anterior-posterior and transverse disc diameters, as detected in the second MRI after an average of 10 treatment sessions over a four-week period of HILT. Additionally, back and leg pain, as well as the angle of straight leg raising, improved in patients whose disc herniation morphology changed.

The change in disc morphology can be attributed to the biological effects of HILT, primarily associated with two major impacts: thermal (increasing the temperature of fluids, leading to changes in phase state and intracellular pressure) and mechanical (resulting from mechanical alterations, kinetic effects, along with ultrasonic influences)¹⁷. Additionally, the pulse characteristics of HILT, which include high peak power at a specific frequency and width, produce a photomechanical effect. This impact arises from the conversion of a portion of the laser light into one or more mechanical forces acting on the tissues. These mechanical forces induce a physical effect on the cell or tissue, causing changes in shape or size, which in turn stimulates cell metabolism, proliferation, and differentiation.¹⁰

One of the consequences of the photothermal effect is mechanical effect. The photothermal effects produced by the laser create local temperature gradients, leading to transitory modifications of the extracellular microenvironment. These changes in the microenvironment alter the mechanical forces on cells, inducing mechanical stress. This stress can modify cell morphology and tissue texture¹¹.

Regarding the impact of conservative treatment on the changes of lumbar disc morphology or size, **Karimi et al., 2017¹⁸** and **Ozturk et al., 2005¹⁹** using segmental traction therapy and continuous lumbar traction respectively in patients with LDH, agree with the findings of the current study in reducing the size of the herniated disc.

Concerning the influence of non-invasive therapy on lumbar disc size modification. The findings of the present study are consistent with those of **Unlu et al. 2008⁶**, who compared the effects of traction, ultrasound, and low-power laser (LPL) on individuals with acute low back pain and leg pain due to LDH. All groups showed significant pain reduction as well as decrease in disability scores, and changes in LDH size. Contrary to our findings, the study reported no correlation between clinical findings, pain and disability scores, and changes in LDH size. This inconsistency may be due to the combination of factors contributing to herniated disc pain, such as nerve root compression, inflammatory cytokine production, and the specific composition of the disc.

Regarding the relationship between the regression of herniated discs and improved clinical outcomes, the findings of the current study align with those of **Kesikburun et al. 2019⁵**, who used MRI to evaluate the effect of conservative treatment on the natural regression of lumbar extruded discs. They also assessed the relationship between radiologic changes and clinical outcomes, finding that pain and disability were linked to disc resorption.

The results of the present study showed a significant reduction of pain level in back and leg and a significant increase of the angle of straight leg raising this can be explained by the analgesic as well as anti-inflammatory effect of HILT.

One possible mechanism by which HILT alleviates pain is by blocking pain signals at multiple levels. The two main effects are an increased pain threshold and a decrease in histamine and bradykinin production from inflammatory tissues. Additionally, laser light inhibits peripheral nociceptors' release of substance P, which aids in reducing pain transmission and avoiding the onset of hyperalgesia. The laser's pain-relieving effects could be attributed to the increased production of natural opioids like β -endorphins, which act centrally to decrease pain. By raising nitric oxide levels, that extend arterial and capillary vessels, encourage electrolyte exchange in the cellular protoplasm, improve the utilization of oxygen, and improve nucleic acid and protein creation, laser therapy may indirectly decrease pain through improving microcirculation within the tissue.^{20&21}

The anti-inflammatory effect is reflected in the modulation of inflammatory reaction components, such as exudation, alteration, and proliferation, as well as by stimulating the organism's readaptive responses. This occurs as a result of inhibitory effects on prostacyclin and prostaglandin synthesis as well as on cyclooxygenases and lipooxygenases. By stimulating the tissue with oscillatory stimulation, the HILT can enhance blood circulation and tissue metabolism. This leads to increased adenosine triphosphate synthesis, enhanced mitochondrial oxidation, and the rapid removal of inflammatory substances, which helps facilitate more efficient absorption of tissue edema.²²

Improvement in clinical manifestation in laser group was Consistent with the findings of **Abdelmageed et al., 2022²³**, who investigated the effects of HILT on clinical manifestations in patients suffering from chronic discogenic sciatica, according to clinical and electrophysiological studies (Hoffmann reflex) that were conducted for evaluation, there were significant decline in pain intensity as well as latency of the Hoffmann reflex (H-reflex) in HILT group.

These findings are in line with those of a previous study by **Boyras et al., 2015²⁴** which examined the efficacy of exercise, high-energy laser therapy, and US on 65 patients suffering from L5-S1 discopathy. They determined that HILT, US, as well as exercise were all successful treatments for lumbar discopathy using the VAS and the Oswestry Disability Index (ODI).

Chen et al. 2017¹², who examined the effects of HILT in individuals with lumbar disc protrusion (LDP), found similar outcomes to the present study. The results demonstrated that HILT considerably reduced pain levels, increased SLR angle, lumbar flexion range, and the ODI.

The results of the current study do not align with those of **Alayat et al. 2014²⁵**, who didn't observe any significant difference among the HILT and sham groups in their study on the effects of high-energy laser therapy in patients with chronic LBP. This discrepancy may be due to differences in study focus, as their research dealt with chronic LBP and whereas our study focused on subacute lumbar disc herniation conditions and employed a different treatment protocol.

LIMITATIONS

During the study, several factors affected the outcomes. The psychological state and level of cooperation of the patients varied, which influenced their participation and adherence to the treatment protocols. Additionally, some patients attended the sessions infrequently, leading to inconsistencies in the treatment received. Furthermore, a number of patients did not undergo the post-treatment MRI scans, resulting in incomplete data for assessing the changes in MRI disc morphology.

CONCLUSION

High-intensity laser therapy has been shown to be a safe and successful rehabilitation technique that can be used to treat individuals with LDH in physiotherapy programs and has an effect on morphology of sub-acute herniated lumbar disc.

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