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Research Article

Effects of low-intensity pulsed ultrasound on pain and functional disability in patients with early-stage lumbar spondylolysis: A randomized controlled trial

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ABSTRACT

Background: Low Intensity Pulsed Ultrasound (LIPUS) is beneficial in accelerating fracture recovery, enhancing their capacity to execute tasks of daily life and, as a result, their autonomy.

Methods: Thirty-four (29 males and 5 females) pre-diagnosed patients referred by an orthopaedic surgeon exhibiting symptomatic low back pain for at least four months were recruited and randomly divided into LIPUS group and Routine Physical Therapy (RPT) group. The lottery method was used to randomly assign patients into two groups. Numeric Pain Rating Scale (NPRS) was utilized for the measurement of pain and Oswestry Disability Index (ODI) for functional disability. Patients were assessed at baseline, at the end of 12th and 20th week. Interventions were applied by the physical therapist having more than eight years of clinical experience for 10 weeks on alternate days.

Results: LIPUS group reported greater reduction in pain with mean change of 3.18 points (95% CI: 2.2, 4.2; $p < 0.001$) at 12th week, 6.18 points (95% CI: 5.5, 6.8; $p < 0.001$) at 20th week follow-up and functional disability with mean change of 28.24 points (95% CI: 23.7, 32.8; $p < 0.001$) at 12th week and 39.47 points (95% CI: 31.8, 47.1; $p < 0.001$) at 20th week follow-up compared with the RPT group.

Conclusion: Low-intensity pulsed ultrasound has significantly reduced pain and functional disability in patients with early-stage lumbar spondylolysis and could be preferred as a safe non-invasive treatment method for early bone healing.

Trial registration: WHO-Iranian registry of clinical trials (IRCT20200206046396N1, Dated: 02/05/2020).

Key Words: Functional disability, Lumbar vertebra, Low-intensity pulsed ultrasound, Pain, Spondylolysis

BACKGROUND

Spondylolysis, a stress fracture of the pars interarticularis of the vertebral arch can affect either the left or right side of the bone. The L5 bone is the site of the vast majority of these injuries, with the L4 bone being the second most likely to be affected. The acuity of the fracture line or bony defect can be divided into 3 stages: early, progressive, and terminal. A hairline fracture can be seen in the early stages. The fracture may have advanced to a broader degree in the progressive stage and the fracture in the terminal stage indicates non-union with no chance of healing [1]. Prevalence of spondylolysis in general population, varies from around 6% to 11.5 % [2] and in professional athletes, the prevalence ranges from 7% to 8%. Nearly half of all low back pain cases in young athletes have been attributed to spondylolysis [3].

Low back pain is aggravated by excessive standing and hyperextension. In nearly 80% of patients, bilateral hamstring tightness, posterior buttock pain spreading to the knees while standing or walking, and potential neurological abnormalities along the L5 or S1 dermatomes that indicate nerve root impingement are common lower extremity findings [4]. Repetitive microtrauma contributing to spondylolysis has been attributed to lumbar hyperextension along with rotation and loading in dancers, gymnasts, figure skaters, weight lifters, and football players [5]. The easiest way to diagnose and plan therapy for spondylolysis is to take a thorough medical history and physical examination [6]. Location, intensity, duration, quality, and exacerbating or alleviating variables can also be included in the pain definition. Precipitating recreation or workplace hazards are two other areas to study [7].

Radiography is used to confirm the clinical diagnosis. Overall, with a sensitivity of 0.82 and specificity of 0.96, [5] Oblique radiographs, [8] which show an appearance of a Scottie dog with a collar, can be used for suspected yet poorly visualized pars defects [9]

LIPUS uses frequencies ranging from 0.75 to 1.5 MHz with intensities of less than 100mW/cm² (usually about 30mW/cm²) and is pulsed at a ratio of 1:4. The transducer head is strapped or otherwise fixed in place and remains stationary for 20 minutes of therapy. For effective sound transmission to deeper tissues, US medium is used once again. In the United States, the FDA approved this modality in 1994 for the treatment of rapid healing of fresh fractures, and again in 2000 for the treatment of confirmed non-union fractures. The findings

submitted to the FDA showed that LIPUS improved angiogenesis, chondrogenesis, and osteogenesis at all three stages of fracture recovery, including inflammatory, reparative, and remodelling. LIPUS causes micro-motion and mechanical stimulus, and thus follows Wolff's Law, which says that bone remodels in response to mechanical stresses. [10]

LIPUS can be effective in early bone healing and its effects should be explored by doing more researches. As far as researcher's knowledge, no randomized controlled trial has been conducted to determine the effects of LIPUS; therefore, the hypothesis of present study was to determine the difference between the effects of routine physical therapy and routine physical therapy along with LIPUS on pain and functional disability in patients with early stage lumbar spondylolysis.

METHODS

Study design and procedure

From 05/06/2020 to 05/06/2021, this randomized controlled trial was conducted as part of a PhD Physical Therapy project at the Department of Physiotherapy, University of Lahore Teaching Hospital, Lahore, Pakistan, using a non-probability purposive sampling technique. After approval from the Institutional Review Board (IRB-UOL-FAHS/690/2020, Dated: 22/01/2020) of the University of Lahore, this study was prospectively registered in the WHO-Iranian registry of clinical trials (IRCT20200206046396N1, Dated: 02/05/2020). Sample size was determined by using WHO sample size software version 2.0. It was calculated as 28, by adding 20% drop out it was 17 in each group. Subjects were divided randomly into two equal groups (LIPUS group and RPT group). Parallel assignment was done. Lottery method was used to randomly assign patients into two groups. NPRS was utilized for the measurement of pain and ODI for functional disability. LIPUS group was treated by low intensity pulsed ultrasound along with routine physical therapy whereas RPT group by routine physical therapy alone.

Participants

Thirty-four (29 males and 5 females) pre-diagnosed patients referred by an orthopaedic surgeon exhibiting symptomatic low back pain for at least four months and were between

the ages of twenty and forty were recruited after they signed a written informed consent form for this research. Patients with the history of neurological or autonomic deficits, other fracture or bony abnormalities, rheumatic disease, other spinal problems, post-menopausal female, osteoporosis and osteopenia were excluded from the study. It was a singled blinded study in which the assessor was kept blinded.

Intervention

Control group (RPT)

Trans Electrical Nerve Stimulation (TENS) was applied for three days a week for 20 minutes per session. The active electrode was positioned in the center of the painful back area, while the second electrode was positioned on the lateral aspect of the thigh. The output frequency was set to 4 to 8 Hz, and the current intensity was increased until the patient reports discomfort. The severity is then lowered to a degree that the patient reported he could tolerate. [11].

Hamstrings were stretched for 15 seconds for three times a day which is helpful for improving spino-pelvic rhythm (lumbar motion/pelvic motion) which is achieved by the flexibility of these muscles, thus decreases tension to the lumbar region [12]. Strengthening of abdominal muscles (transversus abdominis and internal oblique) were performed in 3 sets of 10 repetitions on alternate days which has been shown to reduce pain and functional disability in spondylolysis patients. Thus, provides “stability” to the lumbar spine, maintaining a solid foundation for individuals to incorporate them into their functional activity patterns [13].

Intervention group (RPT+LIPUS)

The following parameters were used in the LIPUS device (Accusonic lipus; Metron Medical Australia, Ltd, Victoria, Australia): 1.1-MHz oscillation frequency, 1-kHz pulsed frequency, 100-mW/cm² spatial intensity, 2ms pulse duration, 100Hz pulse repetition rate, 20% pulse duty cycle, and 20-minute duration on alternate days. Subjects were asked to lie down on a couch in a prone position; a thin (1mm) film of aqua-sonic gel was used as a coupling medium, and a fixed treatment head was positioned over the injured side just lateral to the spine of the lumbar vertebra with the aid of a Velcro strap [10].

Outcome and measurements

NPRS is a 11-point scale for self-report of pain. The respondent selects a whole number (integers 0–10) that best reflects the intensity (or other quality if requested of his/her pain whereas ODI is an extremely important tool that researchers and disability evaluators use to measure a patient's permanent functional disability scored between 0-100%. Thus, higher the score more will be the disability. The subjects were diagnosed and assessed by the same orthopedic surgeon. The same assessor provided his expertise at baseline, at the end of 12th and 20th week. Interventions were applied by the physical therapist having more than eight years of clinical experience for 10 weeks on alternate days.

Statistics

Normality of the data was tested by using Shapiro-Wilk test. Statistically, significant value was agreed at the level of 5%. Descriptive statistics of age, height, weight and BMI were calculated. A repeated measure ANOVA with sphericity assumed for the LIPUS group and with a Greenhouse-Geisser correction for RPT group between assessments points (baseline, 12th and 20th week follow-up). Pairwise comparisons using Bonferroni correction and independent t-test for between group comparisons (baseline, 12th and 20th week follow-up).

RESULTS

Flow chart (Fig. 1)

Baseline characteristics of demographic variables

LIPUS and RPT groups were not significantly different for demographic variables at baseline. Baseline characteristics of the patients are presented in (Table 1).

Within and between group comparison for pain and functional disability at 12th week & 20th week follow-up from baseline

A repeated measure ANOVA with sphericity assumed for the LIPUS group and with a Greenhouse-Geisser correction for RPT group determined that the mean NPRS and ODI

scores for both groups were found statistically significant between assessments points (baseline, 12th week and 20th week follow-up) ($F_{2,32} = 118.90$; $p < 0.001$ for the LIPUS group and $F_{1,979, 31.664} = 20.49$; $p < 0.001$ for the RPT group) of NPRS scores and ($F_{2,32} = 101.98$; $p < 0.001$ for the LIPUS group and $F_{1,152, 18.436} = 4.49$; $p = 0.043$ for the RPT group) of ODI scores respectively.

Pairwise comparisons using Bonferroni correction demonstrated that LIPUS group reported greater reduction in pain with mean change of 3.18 points (95% CI: 2.2, 4.2; $p < 0.001$) at 12th week, 6.18 points (95% CI: 5.5, 6.8; $p < 0.001$) at 20th week follow-up and functional disability with mean change of 28.24 points (95% CI: 23.7, 32.8; $p < 0.001$) at 12th week and 39.47 points (95% CI: 31.8, 47.1; $p < 0.001$) at 20th week follow-up compared with the RPT group (Table 2).

DISCUSSION

This study showed that the LIPUS has significantly reduced pain and functional disability in patients with early-stage lumbar spondylolysis. LIPUS group improved significantly in terms of pain and functional disability compared to RPT group. Therefore, the use of this treatment has a positive effect on patients with lumbar spondylolysis and may be used alone or in combination with other conventional techniques. Very limited researches were available showing the effects of LIPUS on spinal region which had conflicting results. Ebadi et al investigated the effects of LIPUS on chronic non-specific LBP and found low quality evidence of LIPUS on pain relief (MD [95 percent CI] -2.16 [-4.66 to 0.34]; zero to 50-point scale) and functional disability reduction (MD [95 percent CI] -2.16 [-4.66 to 0.34]; zero to 50-point scale) (MD [95 percent CI] -0.41 [-3.14 to 2.32]; per cent) [14]. A similar study by Rubira et al compared the effects of LLLT and LIPUS on chronic non-specific low back pain and demonstrated a reduction in pain ($p < 0.001$), with the LLLT (low-level laser therapy) group showing the greater relative increase (91.2 percent). Meanwhile, the RPT group showed a -5.8% worsening of functional disability ($p < 0.001$), but the LIPUS group showed the greatest relative improvement ($p < 0.001$) (83.3 percent) [15].

Different researches have also been conducted on other body regions to know its effects. A study by Zhou et al systemically reviewed the effect of LIPUS on pain and functional disability in knee osteoarthritis (KOA) patients. The visual analogue scale (VAS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores were compared between the RPT and LIPUS groups using meta-analysis. In comparison to the RPT group, the LIPUS group found a decline in pain severity with mild heterogeneity (-0.79 , 95 percent CI, -1.57 to 0.00 ; $I^2 = 65$ percent, $P = 0.04$) on the VAS and an increase in knee function on the WOMAC (-5.30 , 95 percent CI, -2.88 to -7.71 ; $I^2 = 44$ percent, $P = 0.17$) [16]. Other studies by Jia et al and Raju et al determined the effect of LIPUS on knee osteoarthritis (KOA), and found major differences in VAS and WOMAC after 10 days of treatment, as well as improvements in VAS at 4 and 12 weeks. The mean age of patients in LIPUS and RPT group was 57.08 ± 7.40 and 58.04 ± 9.93 years respectively whereas in our study it was 30.47 ± 5.01 and 30.59 ± 7.32 years respectively [17-18]. Munajat et al evaluated the effects of LIPUS in patients with Total Knee Arthroplasty and found significant ($P < 0.01$) reduction in pain and functional disability [19].

Pain and functional disability has been identified as the most disabling symptom in patients with lumbar spondylolysis. To address this problem a great deal of attention has been paid to specific therapies and supporting ancillary studies. Our results showed better effects on pain and functional disability in LIPUS group with a percentage change of 81% and 65% compared with 37% and 25% in RPT group. A study by D'vaz et al investigated the impact of LIPUS on chronic lateral epicondylitis and found that the LIPUS group had a 64 percent decrease in elbow pain from baseline compared to 57 percent in the RPT group (difference of 7%; 95 percent confidence interval 20 to 35 percent). This was, however, not statistically significant ($P = 0.60$) which might be due to lack of blinding and different predisposing factors effecting on elbow region [20]. Tehranchi et al determined the effect of LIPUS following mandibular surgery and discovered that the reduction in pain reported during the first three weeks after surgery was slightly different between groups ($P < 0.01$) [21]. The study by Warden et al investigated the effectiveness of LIPUS in the reduction of pain symptoms and found no differences in VAS-U (-0.2 cm; 95 percent CI, -1.5 , 1.1 cm) (P

= 0.74) or VAS-W (-0.5 cm; 95 percent CI, -2.1, 1.1 cm) (P = 0.57) were observed between the active- and inactive-LIPUS groups [22].

CLINICAL IMPLICATIONS

The findings of this study have several clinical implications for patients with early-stage lumbar spondylolysis as it is a non-invasive modality which can reduce pain and functional disability without disturbing the daily routine of the patients. Therefore, this approved to be an effective modality to be used by physiotherapists for the treatment of lumbar spondylolysis.

STRENGTHS AND LIMITATIONS

Strength of this study is our sample. We recruited from a variety of surgeons making our results generalizable. There are several limitations to this study. The first limitation was staging. We selected subjects with early-stage lumbar spondylolysis. The second limitation was the age of the subjects. The subjects who participated in this study were young. Therefore, the result of this study cannot be generalized to the entire population.

CONCLUSION

Low-intensity pulsed ultrasound has significantly reduced pain and functional disability in patients with early-stage lumbar spondylolysis and could be preferred as a safe non-invasive treatment method for early bone healing.

Abbreviations

LIPUS: Low-intensity pulsed ultrasound; NPRS: Numeric pain rating scale; ODI: Oswestry disability index; TENS: Trans electrical nerve stimulation (TENS); WOMAC: Western Ontario and Macmaster universities osteoarthritis index; VAS: visual analogue scale; KOA: knee osteoarthritis

DECLARATIONS

Ethics approval and consent to participate

This study was conducted as part of a PhD Physical Therapy project after the approval from the Institutional Review Board (IRB-UOL-FAHS/690/2020, Dated: 22/01/2020) of the University of Lahore, prospectively registered in the WHO-Iranian registry of clinical trials (IRCT20200206046396N1, Dated: 02/05/2020). Subjects were recruited after their written informed consent for this study. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to limitations of ethical approval involving the patient data and anonymity but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that there is no conflict of interest.

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None

Authors' contributions

FT, SAA, HD and AA contributed substantially to the conception and design of the work. SAG, AH was responsible for the acquisition of the data. AH was responsible for the analysis of the data. HD and AH made substantial contributions to the interpretation of the data. FT and SAA drafted the work and substantively revised it. The authors have read and approved the submitted version of the manuscript.

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Table 1: Baseline characteristics of patients

Variables	LIPUS Group	RPT Group	P-value
Age (years)	30.47 ± 5.01 (23-41)	30.59 ± 7.32 (20-41)	0.95
Height (cm)	162.03 ± 7.86	165.20 ± 6.38	0.20
Weight (kg)	60.88 ± 7.59	66.88 ± 8.30	0.30

Body mass index		22.53 ± 2.12	23.06 ± 1.34	0.39
Gender	Male	14 (82%)	15 (88%)	0.62
	Female	3 (18%)	2 (12%)	

Data are expressed as the mean ± standard deviation; LIPUS: Low-intensity pulsed ultrasound; RPT: Routine physical therapy; *p<0.05

Table 2: Within and between group differences for pain and functional disability at 12th week & 20th week follow-up from baseline

Outcome	Assessment point	LIPUS Group		RPT Group	
		Mean	SD	Mean	SD
Pain	Baseline	7.65	0.93	6.06	1.02
	12 th week	4.47	1.73	5.82	1.51
	20 th week	1.47	0.80	3.82	1.28
	Within group change	Mean (95% CI)	P value	Mean (95% CI)	P value
	0-12 weeks	3.18 (2.2-4.2)	< 0.001	0.24 (0.6-1.0)	0.543
	0-20 weeks	6.18 (5.5-6.8)	< 0.001	2.23 (1.5-3.0)	< 0.001
	12-20 weeks	3.00 (2.2-3.8)	< 0.001	2.00 (1.1-2.9)	< 0.001
Functional Disability	Baseline	60.65	10.61	40.65	13.55
	12 th week	32.41	7.61	39.65	13.92
	20 th week	21.18	12.23	30.65	13.63
	Within group change	Mean (95% CI)	P value	Mean (95% CI)	P value
	0-12 weeks	28.24 (23.7-32.8)	< 0.001	1.00 (2.0-4.0)	0.495

0-20 weeks	39.47 (31.8-47.1)	< 0.001	10.00 (0.3-19.7)	0.045
12-20 weeks	11.24 (5.7-16.7)	< 0.001	9.00 (0.0-17.9)	0.048

Data are expressed as the mean \pm SD: standard deviation; LIPUS: Low-intensity pulsed ultrasound; RPT: Routine physical therapy; *p<0.05

Fig.1 Participant selection flowchart according to consort statement.