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ORIGINAL ARTICLE

High-intensity versus low-level laser therapy in the treatment of patients with knee osteoarthritis: a randomized controlled trial

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Abstract The aim of this randomized controlled study was to compare the effects of low-level laser therapy (LLLT) and high-intensity laser therapy (HILT) on pain relief and functional improvement in patients with knee osteoarthritis (KOA). A total of 53 male patients participated in this study, with a mean (SD) age of 54.6 (8.49) years. Patients were randomly assigned into three groups and treated with HILT and exercise (HILT+EX), LLLT and exercise (LLLT+EX), and placebo laser plus exercise (PL+EX) in groups 1, 2, and 3, respectively. The outcomes measured were pain level measured by visual analog scale (VAS) and knee function measured by Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Statistical analyses were performed to compare the differences between baseline and posttreatment measurements. The level of statistical significance was set as $P<0.05$. The result showed that HILT and LLLT combined with exercise were effective treatment modalities in decreasing the VAS and WOMAC scores after 6 weeks of treatment. HILT combined with exercises was more effective than LLLT combined with exercises, and both treatment modalities were better than exercises alone in the treatment of patients with KOA.

Keywords High-intensity laser therapy · Low-level laser therapy · Knee osteoarthritis

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Introduction

Knee osteoarthritis (KOA) is a common musculoskeletal joint disease that affects the elderly [1]. KOA is characterized by degeneration of the articular cartilage in the involved joints and its underlying bone within a joint as well as bony overgrowth [2]. It is one of the major causes of physical disability that has a social and public health impact [3] due to pain, stiffness, joint instability, and muscle weakness [4, 5]. It is believed to be a result of both mechanical and molecular events in the affected joint with gradual onset and usually begins after the age of 40 [6]. Before the age of 50, men are more likely to have KOA than women, but after 50, women are statistically more likely to be affected. One third of people aged 65 years and older have KOA and this is evidenced by radiography [7]. By 65 years of age, more than half of all people report having some degree of joint pain in their neck, hands, back, knees, or hips [8]. In Saudi Arabia, Al-Arfaj and Al-Boukai [9] reported in their study that KOA affects 53.3 % of males and 60.9 % of females with age from 30 to 90 with a mean age of 49 years with bilateral affection of 85.4 % in males and 86.4 % in females [9].

The major cause of functional impairment and disability in people with KOA is pain [7], whereas osteophyte formation, cartilage loss, or periarticular muscle spasm and contracture cause limitation of knee range of motion. In addition, muscle weakness decreases neuromuscular protective mechanisms and increases the functional joint instability which may contribute to the progression of KOA [4, 7].

According to the severity of joint destruction, the treatment of KOA involves both pharmacological and non-pharmacological interventions [10]. Physical therapy modalities are commonly used for pain management that may include magnetic therapy, diadynamic current, ultrasound, and low-level laser therapy (LLLT) [11, 12].

Laser is a non-invasive, painless modality that can be easily administered for a wide range of conditions [13]. LLLT significantly reduces both acute and chronic painful conditions such as rheumatoid arthritis, chronic arthritis, carpal tunnel syndrome, and knee injuries [14–16]. Recently, high-intensity laser therapy (HILT) was introduced to the field of physical therapy. The advantage of HILT over LLLT is that HILT is able to reach and stimulate the large and/or deep joints that are difficult to reach in LLLT [17]. The use of HILT has been proven to significantly reduce pain [18]. Previous studies describe the anti-inflammatory, anti-edematous, and analgesic effects of HILT, thus justifying its use in the therapy of pain [18, 19]. Although Stiglić-Rogoznica et al. [20] reported a significant decrease in pain level after HILT in their study, they recommended comparing the effect of HILT with other conservative interventions or placebo control groups and that further studies should be conducted to measure the functional improvement as a result of pain reduction.

Therefore, the aim of this single-blinded randomized controlled study was to compare the effects of LLLT and HILT on pain relief and functional improvement in patients with KOA.

Methods

Subjects

This study was designed as a single-blinded randomized controlled trial, and it was carried out in the physical therapy department of Umm Al-Qura University, Saudi Arabia. Subjects recruited to the study were from the outpatient department of physical therapy and rehabilitation department of AL-Noor hospital.

Subjects were examined by orthopedic specialists and underwent imaging before a decision was made to include them in the trial. Subjects were included in this study if they (1) had painful KOA for at least 6 months with degenerative osteoarthritic knee of grade 2–3 or less based on radiographic diagnosis in the Kellgren and Lawrence grading of osteoarthritis [21], (2) had no limitation of range of motion except for minimum tightness in the knee joint, (3) did not engage in any high-joint-loading exercises [22] such as hiking or tennis playing and had not undergone any specific treatments 3 months before entering the study, (4) had a minimum score of 25 on the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) total score, and (5) had a knee pain ≥4 on the visual analog scale (VAS) in the previous 3 months [23].

Subjects were excluded from the study at pretreatment evaluation if they had any other musculoskeletal problems associated with the knee joint, such as fracture, tendon or ligament tears, meniscus injury, rheumatoid arthritis, or knee surgery. Patients were also excluded if they had musculoskeletal problems associated with the hip or ankle/foot joints, had central or peripheral neuropathy, or had received physical therapy and/or intra-articular corticosteroid or hyaluronic acid injections during the last 6 months.

Patients were randomized into three groups. Randomization was performed simply by assigning a specific identification number for each patient. These numbers were randomized into the three groups using the SPSS program (IBM, Inc., USA). Patients did not know to which group they were assigned or which treatment they would be offered. Group 1 was treated with HILT and exercise (HILT+EX group), group 2 was treated with LLLT and exercise (LLLT+EX group), and group 3 was treated with placebo laser plus exercise (PL+EX group). After baseline examination, all patients were given a full explanation of the treatment protocol and asked to sign a written informed consent for study participation and for publication of the results.

Assessment of pain

A visual analog scale (VAS) was used for the assessment of knee pain [24, 25]. It is an ordinal scale, using a 100-mm line divided into 10 equal sections, with 0 representing "no pain" and 10 representing "unbearable pain." Each participant was asked to indicate on the scale the level of pain in the knee joint at the baseline and posttreatment after the end of sessions.

Assessment of knee and lower limb functions

The lower limb and knee joint functions could be evaluated by using WOMAC. The WOMAC scale was used to measure pain, stiffness, and physical function. WOMAC is a reliable and valid outcome measure for use in the evaluation of patients with hip osteoarthritis and KOA [26]. The WOMAC was translated to Arabic and was confirmed to be valid and reliable in patients with KOA [27].

Intervention protocols

High-intensity laser therapy

Patients in group 1 received pulsed Nd:YAG laser, produced by HIRO 3 device (ASA, Arcugnano, Vicenza, Italy). A degenerative joint disease (DJD) handpiece was positioned in contact and perpendicularly while the patient in a supine lying position with the knee flexed at 30° to open the joint surfaces to the laser beam (optical windows). The scanning was performed transversely and longitudinally in the anterior, medial, and lateral aspects of the knee joint with emphasis on the application on the joint line between the tibial and femoral epicondyles [20].

The total energy delivered to the patient during one session was 1,250 J through three phases of treatment. The initial phase was performed with fast manual scanning with a total of 500 J. In the initial phase, the laser fluency was set to two successive subphases of 710 and 810 mJ/cm^2 for a total of 500 J. In the intermediate phase, the handpiece was applied on the joint line just proximal to the medial and lateral tibial condyles with 25 J, a fluency of 610 mJ/cm^2, and a time of 14 s for each point and a total of 250 J in this phase. The final phase was the same as the initial phase except that scanning was slow manual scanning. The application time for all three phases was approximately 15 min with the total energy delivered to the patient during one session of 1,250 J. The device calculates the energy received in each phase and the total energy delivered to the patient during the treatment session. HILT was applied for a total of 12 weeks (two sessions/week for 6 weeks). For placebo laser, the patient attended the physical therapy clinic two times a week for 6 weeks and received sham laser.

Low-level laser therapy

Patients in group 2 received gallium-arsenide diode (GaAs) laser (BTL-5000 laser) infrared probes with a wavelength of 830 nm, output power of 800 mW, average energy density of 50 J/cm^2, frequency of 1 KHz, and duty cycle of 80 %. All participants attended to the physical therapy department two times per week over a period of 6 weeks. Patients assumed a supine position lying on the treatment bed while the affected knee was slightly flexed and supported with a pillow. In all cases, the cluster laser was in direct contact and perpendicular to the affected knee with a time of application of 32 min and 33 s per session and a total energy of 1,250 J. LLLT was applied for a total of 12 treatment sessions over a period of six consecutive weeks (two sessions/week). Calibration of laser equipment was done by the manufacturing company through a thermal power meter.

Exercise

Patients in all treatment groups received an exercise program which consisted of active range of motion (ROM) exercises, muscle strengthening, and flexibility exercises. A pre-exercise ROM for the hip, knee, and ankle joints of both lower limbs from supine and prone lying positions in a pain-free range was performed, and then all patients started the exercise session with a 10-min warm-up exercise on the treadmill. Then, each patient performed the quadriceps muscle strengthening exercise 10 times/set, for three sets with a 2-min rest interval in the form of straight leg raising exercise and followed by 5 min of self-stretching for the hamstring and calf muscles [23, 28]. These exercises were repeated at home. Each patient received a handout attached with photographic details of the home-based exercises while the patients were encouraged regarding compliance with the exercise.

Outcomes measured

Demographics like age, gender, weight, body mass index (BMI), marital status, and disease duration were recorded. Baseline evaluation of the measured outcomes was performed at the beginning of the study, and evaluation was repeated after 6 weeks of treatment. The measured outcomes were pain levels and disability scores. Pain level was measured by VAS and knee function by WOMAC.

Data analysis

All analyses were performed using SPSS for Windows, version 16, and GraphPad InStat. Analysis of variance (ANOVA) was used for comparing mean values of patient's age, weight, height, and BMI. For non-parametric measures like VAS and WOMAC, differences between baseline and posttreatment scores for each group were computed by the Wilcoxon signed ranks test. The difference between each treatment group was performed by the Kruskal-Wallis test. The level of statistical significance was set as $P<0.05$.

Results

A preliminary power analysis was used to estimate a proper sample size with 0.80 % power, $\alpha=0.05$, and expected effect size=0.40. The required sample would be 17 patients for each treatment group with a total of 51 subjects. The expected effect size was chosen based on 20 % improvements with 2 points as standard deviation and a significance level of 0.05. Each treatment group was started with 20 subjects for possible dropout. Five subjects (two from group 1 and three from group 3) were excluded or withdrawn from the study because of exercise incompliance and infrequent scheduled treatment sessions.

A total of 53 male patients participated in this study, with a mean (SD) age of 54.6 (8.49) years, mean weight of 86.96 (10.16) kg, mean height of 1.73 (5.57) m, and BMI of 29.09 (4.06) kg/cm^2. Group 1 (HILT+EX) consisted of 20 patients, group 2 (LLLT+EX) consisted of 18 patients, and group 3 (PL+EX) consisted of 15 patients.

There were no significant differences between patients' demographic and physical characteristics among the treatment groups (Table 1). Also, there were no significant differences between the three treatment groups in the baseline of VAS or WOMAC subscales (Table 2).

All treatment groups showed a significant reduction in VAS and WOMAC subscales in posttreatment (after 6 weeks) as compared with baseline values (Table 2). After 6 weeks of treatment, the Kruskal-Wallis test showed a significant difference in the VAS and WOMAC subscales among treatment groups. Dunn's multiple comparisons test showed significant

Table 1 Patient demographic data

	HILT+EX Mean±SD	LLLT+Ex Mean±SD	PL+Ex Mean±SD	*P* value
Age (years)	52.1±6.47	56.56±7.86	55.6±11.02	0.239[a]
Weight (kg)	88.55±7.51	85.16±14.03	87.00±7.75	0.600[a]
Height (m)	1.72±5.49	1.7278±4.917	1.75±6.30	0.330[a]
BMI (kg/cm^2)	29.94±3.360	28.62±5.20	28.51±3.35	0.497[a]
K-L radiological stage (%)				
Grade 2	15 (75)	13 (72.2)	14 (73.3)	
Grade 3	5 (25)	5 (27.7)	4 (26.7)	

HILT high-intensity laser therapy, *LLLT* low-level laser therapy, *PL* placebo laser, *EX* exercises, *SD* standard deviation, *P* probability value

[a] Non-significant difference (one-way ANOVA; $P<0.05$)

differences between the posttreatment scores in pain, WOMAC pain, and function subscales among treatment groups. In WOMAC stiffness subscales, there were significant differences between group 1 and both of groups 2 and 3; however, there were no significant differences between group 2 and group 3 in WOMAC stiffness subscales (mean rank difference was −3.428 and $P>0.05$).

Discussion

This study was conducted to compare the effects of LLLT and HILT on pain relief and functional improvement in patients with KOA. The main findings were that HILT and LLLT combined with exercise are effective in decreasing the VAS and WOMAC scores after 6 weeks of treatment. HILT combined with exercises was more effective than LLLT combined with exercises, and both treatment modalities were better than exercises alone in the treatment of patients with KOA.

Through the available literature, LLLT is considered as an effective treatment modality which is used in the treatment of KOA either in animal models [29] or in humans. Accordingly, LLLT was used alone, combined with acupuncture [30] or exercises [31]. While some authors reported no analgesic effect of laser on patients with KOA [32, 33], other studies proved this effect [23, 31, 34]. Moreover, LLLT was superior to ultrasound in the treatment of patients with KOA [33].

The result of the present study on the effect of LLLT was consistent with that of previous studies in decreasing pain and increasing the level of function. The effects of LLLT on KOA were described by authors as reduction of pain [34], stiffness [34], knee swelling [35], and the intensity of inflammatory process [29]. Meanwhile, it was reported to increase functional performance [23], microcirculations [36], and improvement

Table 2 Changes in VAS and WOMAC among treatment groups

		HILT+EX Mean±SD	LLLT+EX Mean±SD	PL+Ex Mean±SD	*P* value
VAS	Pre	7.80±0.62	7.68±0.658	7.87±0.351	0.422[c]
	6 weeks	2.15±0.75	2.97±0.848	3.93±0.703	>0.0001[a]
	P value	<0.0001[a]	<0.0001[a]	0.001[a]	
WOMAC pain subscale	Pre	9.70±1.41	10.055±1.86	9.80±1.82	0.422[c]
	6 weeks	3.15±1.136	4.77±1.11	6.26±1.22	>0.0001[a]
	P value	<0.0001[b]	<0.0001[b]	0.001[b]	
WOMAC stiffness subscale	Pre	4.10±1.29	3.88±1.13	4.20±0.86	0.779[c]
	6 weeks	1.60±0.68	2.22±0.732	2.40±0.63	0.003[a]
	P value	<0.0001[b]	<0.0001[b]	<0.001[b]	
WOMAC function subscale	Pre	31.70±3.74	30.44±3.66	31.00±3.42	0.556[c]
	6 weeks	13.90±1.86	16.88±2.11	20.60±2.44	>0.0001[a]
	P value	<0.0001[b]	<0.0001[b]	0.0007[b]	

HILT high-intensity laser therapy, *LLLT* low-level laser therapy, *PL* placebo laser, *EX* exercises, *SD* standard deviation, *P* probability value, *VAS* visual analog scale (score: 0–10) measures the intensity of pain (a higher score indicates a higher pain intensity), *WOMAC* Western Ontario and McMaster Universities Arthritis Index (score: 0–96) measures pain (0–20), stiffness (0–8), and function (0–68) (a lower score indicates less dysfunction)

[a] Significant difference in the same measurement interval between treatment groups (Kruskal-Wallis test; $P<0.05$)

[b] Significant difference between the measurement intervals (baseline and 6 weeks) in each treatment group (Wilcoxon signed rank test; $P<0.05$)

[c] Non-significant difference in baseline mean values

of ambulation duration [23]. LLLT reduces pain directly by decreasing the conduction velocity of sensory nerves and raising the pain threshold or indirectly by increasing oxygenation of the tissues and subsequently decreasing swelling [23].

Recently, pulsed Nd:YAG laser therapy, a form of HILT, has been used for a wide range of conditions. HILT applications include recovery of nerve paralysis [37], wound repair [38], and pain relief. It has been used to provide relief from the symptoms of shoulder pain [18], chronic ankle pain [19], and low back pain [39]. In the present study, HILT results were superior to those of LLLT in pain relief and improvement of function. This is supported by the belief that the effect of laser, which can alter cellular and tissue function, depends on the characteristics of the laser itself like wavelength and coherence [40].

With the specific characteristics of pulsed Nd:YAG laser including a wavelength of 1,064 nm, a peak power up to 3,000 W, pulsed emission, regular peaks of elevated values of amplitude with very brief times, and pause time interval to decrease thermal accumulation in tissues, it is able to rapidly induce deep tissue photochemical and photothermal effects [17]. These features result in a greater propagation of radiation in the tissues with a very low histological risk, leading to the possibility of treating deep tissues and structures. At the same time, the photothermal effect can be controlled in terms of patient safety and comfort by modulating the pulse intensity and frequency [41, 42]. That is why Stiglić-Rogoznica et al. [20] in their study demonstrated a very good and quick analgesic effect of HILT in patients with KOA [20].

In the present study, the effect of combined laser therapy and exercise was greater than that of placebo laser with exercise. The results of this study agree with the findings of many studies, that laser therapy has a greater effect than sham laser in treating pain and disability, as measured by VAS, and in improvement of function, as measured by WOMAC [15, 23, 31].

Also, the present study indicates that exercise therapy is clinically able to decrease pain and improve function. It has been proven to be economical, practical, and safe to emphasize the importance of an active exercise program in rehabilitation. However, the combined use of exercise and laser especially HILT has shown to be of clinical significance in providing a rapid and potent effect in pain reduction and functional improvement.

The improvement in the present study was evaluated by VAS and WOMAC. Changes in the muscle strength and power may be needed to correlate these findings in future research. Also, the effect of laser therapy especially HILT on knee cartilage may be needed in future studies as it has been postulated that laser might enhance cartilage regeneration [23].

Conclusion

Laser is an effective physical therapy modality for patients with KOA. In fact, laser (either LLLT or HILT) combined with exercise was more effective than placebo laser with exercise, whereas the effect of HILT combined with exercise is more effective in decreasing pain and increasing functional performance.

Recommendation

HILT is an adjuvant physical therapy modality that may provide better outcomes than LLLT for patients with KOA when used in combination with exercise.

Limitations

The patients were recruited from the male section of the rehabilitation department in the hospital; therefore, all patients were male. Also, the small sample size and time of measurement only after 6 weeks as a short term may be considered as points of limitation, thus emphasizing on choosing a larger sample size and studying the long-term effect in future studies.

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Conflict of interest None

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