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The Effects of High-Intensity Laser Therapy vs. Low-Level Laser Therapy on Functional Ability and Quadriceps Architecture in Patients with Knee Osteoarthritis: A Single-Blinded Randomized Clinical Trial

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Abstract

Introduction: This study aimed to compare the effects of high-intensity laser therapy (HILT) and low-level laser therapy (LLLT) on the disability and architecture of the quadriceps in patients with knee osteoarthritis (OA).

Methods: Ninety-eight patients with knee OA (KOA) were selected by convenience sampling and then divided into three groups: control, LLLT and HILT. Disability was determined using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Quadriceps structures including thickness, fascicle length and pennate angle of the vastus lateralis (VL) and thickness, volume and fiber angle of vastus medialis obliquus (VMO) muscles were assessed using ultrasonography. All evaluations were performed before interventions, immediately after interventions, and one month later. Between-group data were analyzed with two-way ANOVA and paired-samples t-test.

Results: The within-group comparisons of WOMAC scores before, after and at a one-month follow-up showed significant differences between the groups ($P<0.001$). The VMO thickness revealed significant increases after the treatment in both HILT ($P<0.001$) and LLLT ($P=00.03$) groups. The between-group comparison revealed a significantly lower score of WOMAC in the HILT group compared to the other groups after a one-month follow-up ($P=00.03$). VMO thickness showed a significant increase in the HILT group after the treatment ($P=0.002$). The VL structures and VMO fiber angle and volume did not exhibit significant changes in within-group and between-group comparisons ($P>00.05$).

Conclusion: Both HILT and LLLT may improve functional ability and VMO thickness in patients with knee osteoarthritis. After a one-month follow-up, functional ability was greater in the HILT group.

Keywords: Osteoarthritis; Knee; High-intensity laser therapy; Low-level laser therapy; Photobiomodulation.

Introduction

Osteoarthritis (OA) is the most common degenerative musculoskeletal disorder, mainly occurring in old age.[1] The disease is caused by various physiological, biomechanical, and biochemical changes in articular cartilage. These changes cause gradual degeneration of the articular cartilage and deformation of the subchondral bone.[2,3] Prolonged synovitis with joint damage due to OA can lead to capsular fibrosis and restricted range of motion. Muscle reflex inhibition due to pain and swelling can cause muscle atrophy and unbalanced forces around the joint. This can lead to functional impairment and disability. Moreover, reduced joint space due to degenerative bone can lead to laxity of the ligaments.

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Thereafter, the structural changes cause biomechanical instability, creating a faulty degenerative joint as well as a local synovial inflammation cycle.[4]

According to the latest statistics of the World Health Organization, it has been estimated that by 2031, OA will be in the top 4 common causes of disability globally. Moreover, severe levels of disability will become apparent in about 10 million people in developed countries and 33.5 million people in developing countries, totaling more than 44 million people worldwide.[5]

OA is most common in the knee joint. Knee OA (KOA) restricts daily activities in afflicted people, diminishing the quality of life and limiting social activities.[6] Approximately 250 million people globally are affected by KOA, and this number is expected to increase in the future.[7] According to epidemiological studies in Iran, about 21% in rural areas and about 17% of people aged over 15 in urban areas are suffering from some form and degree of OA, and 25% of all cases are suffering from KOA.[8] KOA symptoms include joint stiffness, pain, limitation in range of motion, altered muscle activity, decreased quality of life, and disability.[2]

The treatments available for KOA are categorized into non-surgical and surgical procedures.[9] Non-surgical treatments include both pharmacological and non-pharmacological interventions.[3,10] Non-pharmacological treatments include dry needling, knee braces and medical insoles, hydrotherapy, self-management, exercise training, and physiotherapy interventions.[11,12] Pharmaceutical agents include non-steroidal anti-inflammatory drugs, glucosamine, and chondroitin, along with an intra-articular injection with corticosteroid compounds or lubricating supplements such as hyaluronic acid.[10]

Physiotherapy interventions for OA include electrophysical agents, manual therapy, and exercise therapy.[13] The physiotherapy goals include the prevention of stress and trauma on the involved joint, improvement in muscle strength and cartilage nutrition by re-establishing physiological movements, and pain reduction.[14] In recent years, photobiomodulation (PBM) has been considered as a non-surgical and non-pharmacological therapeutic intervention. PBM is a low-cost, safe, and non-invasive method of radiating the laser light into the target tissues.[15,16] Based on safety classifications, there are two main types of laser PBM: low-level laser therapy (LLLT) with the mean power output of less than 500 mW and high-intensity laser therapy (HILT) with the mean power output of more than 500 mW. Several studies have been conducted on the effects of these two types of laser PBM and the differences between them.[17]

LLLT, as PBM therapy, is considered a non-thermal electrophysical agent. It has been used for decades, and its effectiveness has already been studied in musculoskeletal disorders.[18] It is effective in reducing pain and edema and improving blood circulation, thereby enhancing physical performance and quality of life.[19] Recently, in a review, Malik et al. showed that LLLT plus exercise is not superior to sham LLLT plus exercise when assessing the range of motion, strength and function in KOA.[20] Nevertheless, some studies revealed more effects of LLLT relative to other interventions in KOA.[21,22] In recent years, HILT has increasingly been used in physiotherapy.[23] The average output power of HILT is higher than LLLT, which may subsequently lead to more energy delivery to tissues, deeper penetration, lower treatment time, and perhaps other physiological effects.[24] HILT causes thermal, mechanical, photochemical, and electrical changes at the cellular level, leading to pain and inflammation reduction, extracellular component activity increase, mitochondrial aerobic capacity, ATP production, lymph flow, and acceleration of the healing process.[25]

Previous studies of PBM have focused on subjective variables such as pain, disability, and swelling. In a review paper, HILT was shown to be more effective than LLLT on self-reported functional ability and pain outcomes in patients with KOA.[26] However, few studies have evaluated and compared the effects of LLLT and HILT on soft tissue structures,[27,28] and no study has compared the effect of these two types of laser PBM methods of delivery on muscle structure using ultrasonography as an objective outcome in people with KOA. Due to the lack of evidence and the similarities and differences in the physical parameters of the delivered energy, this study aimed to compare the effects of HILT and LLLT on functional ability, and the structure of the vastus medialis obliquus (VMO) and vastus lateralis (VL) muscles in people with KOA.

Methods and Materials

Participants

The present study was carried out as a prospective, single-blind randomized controlled trial design, in which only the participants were blinded. Patients with OA referred to Poursina Hospital (Guilan, Iran) were included in this study. The inclusion criteria were: 1. Patients with knee pain and radiological findings of KOA (grades 1 and 2 of Kellgren-Lawrence classification); 2. Body mass index ≤ 40; 3. Age between 45 and 60 years old. As per Jankaew et al, patients were excluded with: KOA radiological findings of Kellgren-Lawrence grades 3 and 4, a history of rheumatoid arthritis, malignancy, local knee infection, knee surgery, fracture, complete meniscus or cruciate ligament rupture, neuropathic diseases, injection of hyaluronic acid or corticosteroid in the past six months, and physiotherapy in the last month.[21]

Ninety-eight patients with KOA were selected by convenience sampling and randomly assigned to the following three groups: Group 1 was treated with a standardized physiotherapy protocol (control group), Group 2 was treated with LLLT plus physiotherapy

(LLLT group), and Group 3 was treated with HILT and physiotherapy (HILT group). Randomization was performed by a free software program generating a random number table. The hospital secretary performed this task prior to commencement of the study (Figure 1).

After baseline examinations, all participants were fully informed of the treatment protocol prior to signing written informed consent. The participants were evaluated before the treatment, immediately after the end of the intervention, and one month after the last session of the treatment. The present study protocol complied with the Consolidated Standards of Reporting Trials guidelines for clinical trials with the IRCT20170516034003N5 registration code on https://irct.behdasht.gov.ir/trial/38937.

Assessment of Disability

The Persian version of the Western Ontario and McMaster Osteoarthritis Index (WOMAC) questionnaire was used to evaluate relevant domains of KOA. The scale includes 24 questions about pain, joint stiffness, and physical function. Each question is graded from 'none' to 'very severe' on a 0 to 4 scale, respectively.[29] The Persian WOMAC questionnaire has high validity and reliability for patients with KOA.[30] The WOMAC score, VMO, and VL thickness were considered as primary variables, while the fiber angle and volume of VMO, and fascicle length and pennate angle of VL were considered as secondary variables.

The VMO and VL Muscles Ultrasonography

Ultrasound measurements (Chison ECO, China) were made using a B-mode 5-7 MHz linear transducer. The participants were assessed in the supine position with knees and feet in the neutral position. A line from the superior pole of the patella to the anterior superior iliac spine was marked on the patient's skin. The thickness of the VL muscle was measured at 50% of this distance and at 10% of thigh circumference in the lateral direction according to the method described previously.[31] Once the measurement point was determined, according to the method described by Raj et al, the muscle "pennation angle was measured as the angle between the muscle fascicles and the deep aponeurosis, and fascicle length was measured as the length of a fascicle between its insertions at the superficial and deep aponeurosis" (Figure 2).[32] The thickness of the VMO was measured at 2 cm above the patella and 12.5% of thigh circumference in the medial direction.[31] By moving the probe into the caudal position, the volume of VMO was observed.[33] In order to measure the fiber angle of the VMO, when the VMO fibers were seen to be parallel, the angle between the borderline of the ultrasound probe to the line from the anterior superior iliac spine to the center of the patella was measured (Figure 3).[34]

Intervention Protocols

Control Group

The control group interventions consisted of an infrared

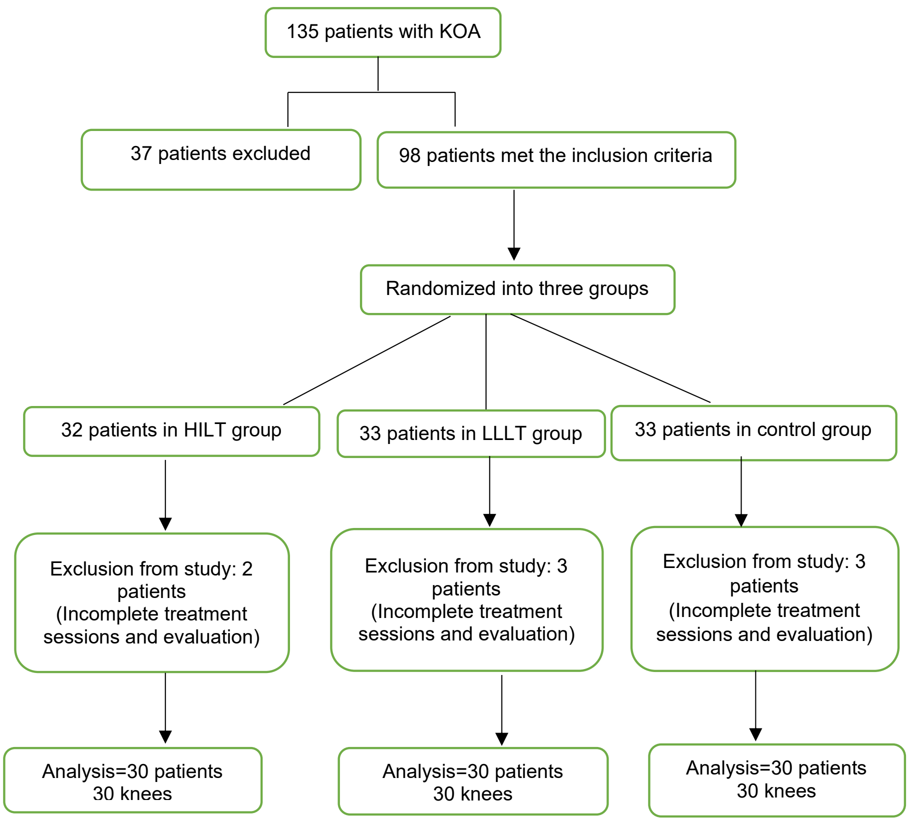

Figure 1. Participants' Flow Chart. KOA: Knee osteoarthritis, HILT: High-intensity laser therapy, LLLT: Low level laser therapy

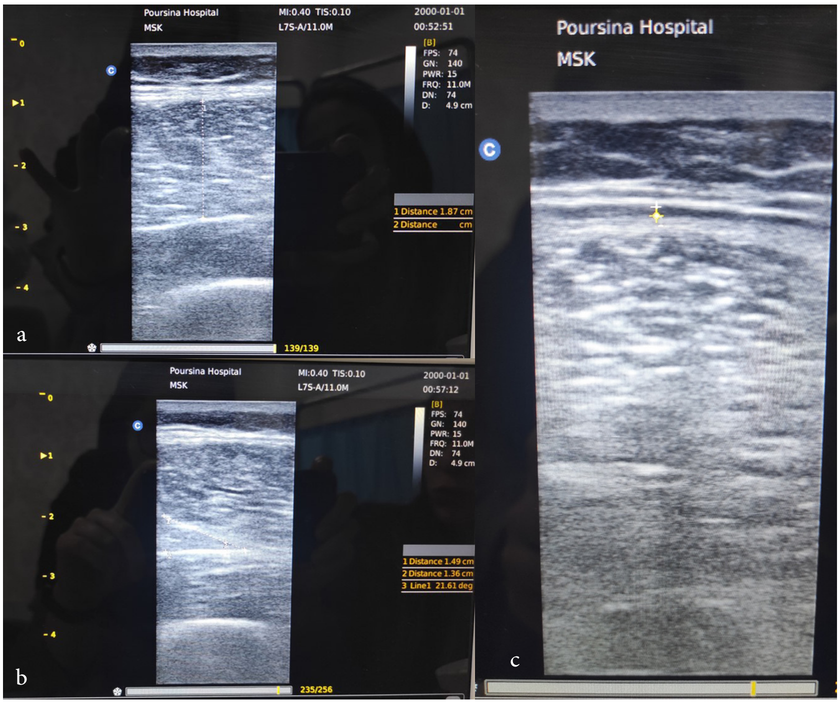

Figure 2. Vastus Lateralis Ultrasonography: (a) Thickness, (b) Pennation Angle, (c) Fascicle Length

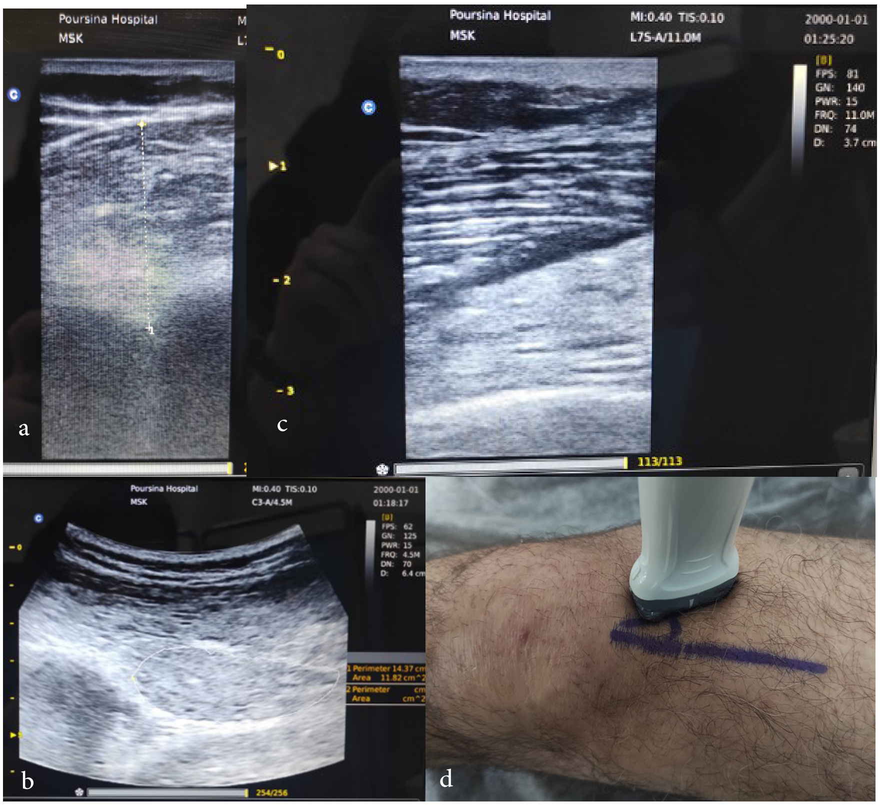

Figure 3. Vastus Medialis Oblique Ultrasonography: (a) Thickness, (b) Volume, (c,d) Fiber Angle

lamp (Novin Company, Iran) for 20 minutes at a distance of 50 cm from the skin and transcutaneous electrical nerve stimulation (Novin company, Iran) for 20 minutes with a modulating frequency of 3-120 Hz. The exercise program included (*a*) The patient pulled their foot towards themselves in a long sitting position by an elastic band (for calf muscle stretching), and straight leg raising for hamstring muscle stretching, three sets of 30 seconds; (*b*) Isometric strengthening exercise of the quadriceps, for three sets of 10 repetitions, and isotonic contractions on quadriceps table, for three sets of 10 repetitions (the weight resistance was set based on each patient's tolerance).

LLLT Group

In addition to the interventions undertaken by the control group, the LLLT group received laser PBM at an 808 nm wavelength, with an output peak and average power of 50 mw, energy density of 12 J/cm^2, continuous mode, single diode probe, and spot size: 0.19 cm^2 (CARCI Med Ltd Company, Brazil). The participants were in the supine position with the affected knee in 30-degree flexion and supported by a pillow. There were four application points at the medial knee, four points to the lateral knee, one supra-patellar point, and one infra-patellar point.[35] The laser probe was applied in direct contact with the skin at each point, and the total radiation time to the knee was 912 s per treatment session.[21] Calibration of the laser was done every six months (Figure 4).

HILT Group

In addition to the interventions in the control group, participants in the third group received HILT (808 nm, 1600 mW + 650 nm visible beam, Elettronica Pagani, Italy). The patients were in the supine position and the knee was flexed at 30 degrees by a pillow. A scanning technique was performed transversely and longitudinally to the anterior, medial, and lateral aspects of the knee joint. The area of irradiation was 20 cm^2 and the parameters of the laser were as follows: wavelength of 808 nm, output power 1.6 W, and energy density of 12 J/cm^2, continuous mode, and irradiation area: 20 cm^2. The treatment time was 300 s per session (Figure 5). The parameters for intervention groups were selected according to recent evidence and devices which were available in practice [21, 25, 36]. All participants received ten consecutive treatment sessions over two weeks. Participants who did not complete the required number of sessions were excluded from the study.

Data analysis

A paired t-test was performed to examine within-group changes, and two-way ANOVA (3 × 3) was performed for between-group differences. The post-hoc Bonferroni analysis was used to compare specific group differences. In the current study, SPSS/PC Ver. 19.0 was used for statistical processing and the statistical significance level was set at $\alpha = 0.05$.

To determine the final sample size, first, a preliminary study was performed on 15 patients; then, using the data, the final sample size was determined according to the following formula (95% confidence and 90% test power):

$$n = \left(\frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta} \right) 2(S1 + S2)}{(\mu_1 - \mu_2)2} \right)$$

Results

Ninety participants completed the study with participants equally divided into three study groups (n = 30). Figure 1 represents the participant flow chart.

Table 1 shows the demographic and baseline clinical characteristics of the participants with OA. There were no significant differences in terms of demographic information between the groups. The baseline scores of WOMAC, muscle thickness, fascicle length and pennate angle of the VL muscle, and thickness, volume and fiber angle of the VMO showed no significant differences between the groups before the interventions (Table 2).

There were significant differences in within-group comparisons (Table 2) before interventions, after interventions, and at a one-month follow-up in the three groups' WOMAC disability scores ($P < 0.001$). The between-group comparison revealed a significantly lower score of WOMAC in the HILT group compared to other groups after a one-month follow-up ($P = 0.03$). There were no significant differences between the groups after the end of 10-session treatment ($P = 0.79$). The within-group comparisons showed that the VMO thickness increased significantly in HILT ($P < 0.001$) and LLLT

Figure 4. Low-Level Laser Therapy

Figure 5. High-Intensity Laser Therapy

Table 1 The Demographic and Clinical Characteristics of the Subjects in All Groups

Variable		HILT Group (mean ± SD)	LLLT Group (mean ± SD)	Control Group (mean ± SD)	*P* Value
Age		50.47 ± 7.45	51.0 ± 8.80	49.83 ± 7.39	0.849
BMI		28.26 ± 6.41	30.10 ± 2.72	31.04 ± 6.20	0.132
Dominant leg	Right	14 (46.7)	22 (73.3)	20 (66.7)	0.08
	Left	16 (53.3)	8 (26.7)	10 (33.3)	
Affected leg	Right	15 (50)	15 (50)	15 (50)	1.00
	Left	15 (50)	15 (50)	15 (50)	
K-L radiographs	Grade 1	16 (53.3)	10 (33.3)	12 (40)	0.56
	Grade 2	14 (46.7)	20 (66.7)	18 (60)	

HILT: High-intensity laser therapy, SD: Standard deviation, LLLT: Low level laser therapy, BMI: Body mass index, K-L: Kellgren-Lawrence.

Table 2 Changes in WOMAC and Architecture of VL and VMO Among Treatment Groups After 10 Sessions and 1-Month Follow-up

Variable	Time	Group			*P* Value
		HILT group (mean ± SD)	LLLT group (mean ± SD)	Control group (mean ± SD)	
WOMAC	Before	49.23 ± 21.86	57.73 ± 21.21	49.83 ± 17.06	0.19
	After	37.53 ± 24.07	41.20 ± 20.82	38.60 ± 19.57	0.79
	Follow up	28.40 ± 20.77	44.10 ± 23.33	35.47 ± 24.02	0.03*
	P value	< 0.001*	< 0.001*	< 0.001*	
Thickness of VL	Before	18.87 ± 4.25	17.12 ± 5.05	18.88 ± 3.77	0.20
	After	18.01 ± 4.09	17.13 ± 5.21	18.63 ± 4.25	0.44
	Follow up	18.15 ± 3.91	18.25 ± 6.43	18.99 ± 4.19	0.77
	P value	0.40	0.33	0.53	
Fascicle Length of VL	Before	1.49 ± 0.48	1.28 ± 0.44	1.54 ± 1.74	0.60
	After	1.59 ± 0.55	1.52 ± 1.13	1.46 ± 0.67	0.83
	Follow up	1.54 ± 0.54	1.31 ± 0.54	1.25 ± 0.40	0.07
	P value	0.97	0.70	0.28	
Pennate angle of VL	Before	19.80 ± 5.88	18.33 ± 6.43	18.50 ± 5.70	0.58
	After	18.23 ± 6.39	16.06 ± 6.13	18.70 ± 7.25	0.26
	Follow up	20.36 ± 6.18	17.00 ± 6.76	18.66 ± 6.21	0.13
	P value	0.31	0.12	0.66	
Thickness of VMO	Before	30.73 ± 7.11	29.85 ± 6.77	29.48 ± 6.51	0.06
	After	34.94 ± 7.62	28.45 ± 8.54	29.08 ± 5.84	0.002*
	Follow up	33.54 ± 8.31	32.57 ± 7.42	31.55 ± 6.15	0.58
	P value	< 0.001*	0.02*	0.15	
Fiber angle of VMO	Before	47.90 ± 9.66	49.83 ± 9.95	48.76 ± 13.45	0.79
	After	51.76 ± 11.02	50.94 ± 14.47	46.13 ± 11.61	0.17
	Follow up	51.83 ± 11.99	45.83 ± 11.86	48.40 ± 12.10	0.15
	P value	0.13	0.42	0.67	
Volume of VMO	Before	3.89 ± 0.93	3.44 ± 1.16	4.03 ± 1.13	0.09
	After	3.65 ± 1.05	3.39 ± 1.00	3.98 ± 1.11	0.05
	Follow up	3.93 ± 1.10	3.50 ± 1.34	3.99 ± 1.14	0.13
	P value	0.06	0.23	0.23	

WOMAC: Western Ontario and McMaster Universities Index, VL: Vastus lateralis, VMO: Vastus medialis obliquus, HILT: High-intensity laser therapy, SD: Standard deviation, LLLT: Low-level laser therapy.
* Significant.

($P = 0.03$) groups. VMO thickness showed a significant increase in the HILT group after the end of 10 sessions of treatment in the between-group comparisons ($P = 0.002$). The fiber angle and volume of the VMO in the within- and between-group comparisons showed no significant differences before or after the treatment or at a one-month follow-up ($P > 0.05$). The thickness, fascicle length, and pennate angle of VL muscle did not change (Table 2).

Discussion

The findings of the present study showed that both HILT and LLLT improved the functional ability and VMO thickness in patients with KOA. Although functional ability increased in the HILT group, VMO thickness was similar between all groups at a one-month follow-up. The VL structures did not change in within- and between-group comparisons. Therefore, it is not clear how changes in muscle thickness may have been related to the outcomes measured by the WOMAC tool, and further study is warranted.

The LLLT has been previously found to stabilize calcium, sodium, and potassium ions and improve ATP production by affecting mitochondria, thereby increasing blood flow and removing the inflammatory substances from the environment. In humans, LLLT slows nerve conduction velocity and can reduce compound action potential amplitude.[27] As noted by Wickenheisser et al, laser therapy can reduce or inhibit prostaglandin E2 and inflammatory cytokines such as tumor necrosis factor alpha (TNF- α), nuclear factor kappa B (NF-κB), cyclooxygenase-2, and interleukin (IL)-1β.[37].Consequently, the LLLT may not only influence the KOA pain, stiffness, and inflammation but also increase blood flow in the tissues around the knee.[38,39] Jankaew et al showed that LLLT with an 808 nm wavelength may improve knee extensor strength and functional performance in patients with KOA.[21] Whilst the mechanism and physiological effects of the LLLT are now relatively well-established, the literature regarding the HILT remains in its infancy by comparison.[25] Theoretically, due to its power per pulse, short pulse duration, and long inter-pulse interval, the HILT may deliver energy to greater tissue depth in a shorter period without causing tissue damage.[24,40] Yet, the HILT may be less well absorbed by chromophores, and its thermal, mechanical, electrical, and photochemical effects should be further studied.[23,28]

The findings of the present study regarding the effects of LLLT on functional ability were similar to those of previous studies.[41] In a study by Gendy et al, the patients with grade 2 and grade 3 KOA were irradiated using LLLT around the knee. They concluded that LLLT was effective in pain reduction and functional ability of the patients with KOA.[42] Furthermore, Elboim-Gabyzon and Nahhas revealed immediate effects of LLLT on pain and function in patients with KOA.[43] The benefit of adding PBM to an exercise program was demonstrated in another study by Youssef et al, who compared WOMAC disability outcomes in an exercise-only group with two other groups receiving exercise plus different combinations of LLLT parameters. In their study, the within- and between-group comparisons showed that functional ability improved significantly despite the low sample size and lower energy density compared to our study.[44] Increasing blood supply and myogenin, modifying gene expression, and decreasing creatine kinase may be mechanisms of LLLT related to the improvements noted in functional ability in OA patients.[42,43,45] However, in some studies, both LLLT and HILT did not improve pain and functional ability in OA patients, especially in a long-term follow-up.[24,46]

Almost all research studies on PBM in KOA emphasize pain as a main outcome.[22,47] Pain levels may be influenced by the ability of muscles (strength) to control the stability of an arthritic joint. In the present study, we considered muscle activity as a primary variable to assess the effects of PBM. The findings of the present study revealed that HILT increased the VMO thickness in the short term, an interesting outcome. Neuromuscular facilitation using electrical muscle stimulation occurs in part by increasing motor unit recruitment, thus changing muscle activation in the short term, which is the first step towards improving muscle morphology.[48] As far as we are aware, such a mechanism has not been shown as a consequence of PBM. The possibility of improved muscle activation in the long term, such as a three- or six-month follow-up, remains an intriguing concept.

Recently, Ahmad et al compared the efficacy of LLLT and HILT in patients with KOA. The findings showed that HILT is more effective than LLLT in pain reduction and functional ability in these patients.[49] All outcomes in Ahmad and colleagues' study were self-reported, and they did not mention the mechanism of HILT effectiveness. However, Astri et al showed that HILT analgesic and functional effects were faster and greater relative to LLLT in KOA. HILT penetrates the therapeutic area widely and accelerates the repair process by anti-inflammatory effects which may increase blood circulation and cause vascular, lymphatic, and neural changes.[36] A network meta-analysis has shown that HILT induced long-term effects on VAS pain and WOMAC function in KOA, in comparison with LLLT.[26]

Studies comparing LLLT and HILT have increased. Although, in some studies, HILT was more effective as an analgesic modality compared to LLLT, the body of evidence is not yet mature enough to confirm any difference regarding other outcomes such as muscle activity and gait biomechanics.[24,25,28] In future studies, consideration of objective outcomes along with a long-term follow-up should be undertaken to compare the effects of HILT and LLLT in patients with KOA.[26]

Limitations

We evaluated only the quadriceps muscle activity by ultrasonography in patients with KOA. Changes in the activity pattern of other periarticular musculature such as the hamstrings may have impacted the findings. The lack of long-term follow-up was another limitation of the present study. We did not consider the control group without any treatment due to ethical concerns.

Conclusion

Both HILT and LLLT may improve the functional ability and VMO thickness in patients with KOA. HILT was more effective than LLLT for knee functional ability at a one-month follow-up. The findings of the present study revealed that laser PBM, especially HILT, should be considered in KOA management. Future studies should be done using objective outcomes to clarify laser PBM effects on OA.

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Competing Interests

The authors declare no conflict of interest.

Ethical Approval

The study was approved by the ethics committee of Guilan University of Medical Sciences (IR.GUMS.REC.1397.366).

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References

1. Murphy LB, Moss S, Do BT, Helmick CG, Schwartz TA, Barbour KE, et al. Annual incidence of knee symptoms and four knee osteoarthritis outcomes in the Johnston County Osteoarthritis Project. Arthritis Care Res (Hoboken). 2016;68(1):55-65. doi: 10.1002/acr.22641.
2. Lespasio MJ, Piuzzi NS, Husni ME, Muschler GF, Guarino A, Mont MA. Knee osteoarthritis: a Primer. Perm J. 2017;21:16-183. doi: 10.7812/tpp/16-183.
3. Mora JC, Przkora R, Cruz-Almeida Y. Knee osteoarthritis: pathophysiology and current treatment modalities. J Pain Res. 2018;11:2189-96. doi: 10.2147/jpr.S154002.
4. Mathiessen A, Conaghan PG. Synovitis in osteoarthritis: current understanding with therapeutic implications. Arthritis Res Ther. 2017;19(1):18. doi: 10.1186/s13075-017-1229-9.
5. Sharif B, Garner R, Hennessy D, Sanmartin C, Flanagan WM, Marshall DA. Productivity costs of work loss associated with osteoarthritis in Canada from 2010 to 2031. Osteoarthritis Cartilage. 2017;25(2):249-58. doi: 10.1016/j.joca.2016.09.011.
6. Roos EM, Arden NK. Strategies for the prevention of knee osteoarthritis. Nat Rev Rheumatol. 2016;12(2):92-101. doi: 10.1038/nrrheum.2015.135.
7. Wallace IJ, Worthington S, Felson DT, Jurmain RD, Wren KT, Maijanen H, et al. Knee osteoarthritis has doubled in prevalence since the mid-20th century. Proc Natl Acad Sci U S A. 2017;114(35):9332-6. doi: 10.1073/pnas.1703856114.
8. Moghimi N, Davatchi F, Rahimi E, Saidi A, Rashadmanesh N, Moghimi S, et al. WHO-ILAR COPCORD study (stage 1, urban study) in Sanandaj, Iran. Clin Rheumatol. 2015;34(3):535-43. doi: 10.1007/s10067-013-2430-0.
9. Lim WB, Al-Dadah O. Conservative treatment of knee osteoarthritis: a review of the literature. World J Orthop. 2022;13(3):212-29. doi: 10.5312/wjo.v13.i3.212.
10. Gregori D, Giacovelli G, Minto C, Barbetta B, Gualtieri F, Azzolina D, et al. Association of pharmacological treatments with long-term pain control in patients with knee osteoarthritis: a systematic review and meta-analysis. JAMA. 2018;320(24):2564-79. doi: 10.1001/jama.2018.19319.
11. Arden NK, Perry TA, Bannuru RR, Bruyère O, Cooper C, Haugen IK, et al. Non-surgical management of knee osteoarthritis: comparison of ESCEO and OARSI 2019 guidelines. Nat Rev Rheumatol. 2021;17(1):59-66. doi: 10.1038/s41584-020-00523-9.
12. Kan HS, Chan PK, Chiu KY, Yan CH, Yeung SS, Ng YL, et al. Non-surgical treatment of knee osteoarthritis. Hong Kong Med J. 2019;25(2):127-33. doi: 10.12809/hkmj187600.
13. Walsh NE, Pearson J, Healey EL. Physiotherapy management of lower limb osteoarthritis. Br Med Bull. 2017;122(1):151-61. doi: 10.1093/bmb/ldx012.
14. Kloek CJ, van Dongen JM, de Bakker DH, Bossen D, Dekker J, Veenhof C. Cost-effectiveness of a blended physiotherapy intervention compared to usual physiotherapy in patients with hip and/or knee osteoarthritis: a cluster randomized controlled trial. BMC Public Health. 2018;18(1):1082. doi: 10.1186/s12889-018-5975-7.
15. Gendron DJ, Hamblin MR. Applications of photobiomodulation therapy to musculoskeletal disorders and osteoarthritis with particular relevance to Canada. Photobiomodul Photomed Laser Surg. 2019;37(7):408-20. doi: 10.1089/photob.2018.4597.
16. Vassão PG, Parisi J, Penha TF, Balão AB, Renno AC, Avila MA. Association of photobiomodulation therapy (PBMT) and exercises programs in pain and functional capacity of patients with knee osteoarthritis (KOA): a systematic review of randomized trials. Lasers Med Sci. 2021;36(7):1341-53. doi:

10.1007/s10103-020-03223-8.

17. Jorge AE, Dantas LO, Serrão PR, Alburquerque-Sendín F, Salvini TF. Photobiomodulation therapy associated with supervised therapeutic exercises for people with knee osteoarthritis: a randomised controlled trial protocol. BMJ Open. 2020;10(6):e035711. doi: 10.1136/bmjopen-2019-035711.
18. Liao FY, Lin CL, Lo SF, Chang CC, Liao WY, Chou LW. Efficacy of acupoints dual-frequency low-level laser therapy on knee osteoarthritis. Evid Based Complement Alternat Med. 2020;2020:6979105. doi: 10.1155/2020/6979105.
19. Rayegani SM, Raeissadat SA, Heidari S, Moradi-Joo M. Safety and effectiveness of low-level laser therapy in patients with knee osteoarthritis: a systematic review and meta-analysis. J Lasers Med Sci. 2017;8(Suppl 1):S12-9. doi: 10.15171/jlms.2017.s3.
20. Malik S, Sharma S, Dutta N, Khurana D, Sharma RK, Sharma S. Effect of low-level laser therapy plus exercise therapy on pain, range of motion, muscle strength, and function in knee osteoarthritis - a systematic review and meta-analysis. Somatosens Mot Res. 2023;40(1):8-24. doi: 10.1080/08990220.2022.2157387.
21. Jankaew A, You YL, Yang TH, Chang YW, Lin CF. The effects of low-level laser therapy on muscle strength and functional outcomes in individuals with knee osteoarthritis: a double-blinded randomized controlled trial. Sci Rep. 2023;13(1):165. doi: 10.1038/s41598-022-26553-9.
22. Oliveira S, Andrade R, Valente C, Espregueira-Mendes J, Silva FS, Hinckel BB, et al. Effectiveness of photobiomodulation in reducing pain and disability in patients with knee osteoarthritis: a systematic review with meta-analysis. Phys Ther. 2024;104(8):pzae073. doi: 10.1093/ptj/pzae073.
23. Wyszyńska J, Bal-Bocheńska M. Efficacy of high-intensity laser therapy in treating knee osteoarthritis: a first systematic review. Photomed Laser Surg. 2018;36(7):343-53. doi: 10.1089/pho.2017.4425.
24. Kim GJ, Choi J, Lee S, Jeon C, Lee K. The effects of high intensity laser therapy on pain and function in patients with knee osteoarthritis. J Phys Ther Sci. 2016;28(11):3197-9. doi: 10.1589/jpts.28.3197.
25. Ezzati K, Laakso EL, Salari A, Hasannejad A, Fekrazad R, Aris A. The beneficial effects of high-intensity laser therapy and co-interventions on musculoskeletal pain management: a systematic review. J Lasers Med Sci. 2020;11(1):81-90. doi: 10.15171/jlms.2020.14.
26. Khalilizad M, Hosseinzade D, Marzban Abbas Abadi M. Efficacy of high-intensity and low-level laser therapy combined with exercise therapy on pain and function in knee osteoarthritis: a systematic review and network meta-analysis. J Lasers Med Sci. 2024;15:e34. doi: 10.34172/jlms.2024.34.
27. Ezzati K, Laakso EL, Saberi A, Yousefzadeh Chabok S, Nasiri E, Bakhshayesh Eghbali B. A comparative study of the dose-dependent effects of low level and high intensity photobiomodulation (laser) therapy on pain and electrophysiological parameters in patients with carpal tunnel syndrome. Eur J Phys Rehabil Med. 2020;56(6):733-40. doi: 10.23736/s1973-9087.19.05835-0.
28. Saleh MS, Shahien M, Mortada H, Elaraby A, Hammad YS, Hamed M, et al. High-intensity versus low-level laser in musculoskeletal disorders. Lasers Med Sci. 2024;39(1):179. doi: 10.1007/s10103-024-04111-1.
29. Bellamy N. Validation study of WOMAC: a health status instrument for measuring clinically important patient-relevant outcomes following total hip or knee arthroplasty in osteoarthritis. J Orthop Rheumatol. 1988;1:95-108.
30. Ebrahimzadeh MH, Makhmalbaf H, Birjandinejad A, Golhasani Keshtan F, Hoseini HA, Mazloumi SM. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) in Persian speaking patients with knee osteoarthritis. Arch Bone Jt Surg. 2014;2(1):57-62.
31. Giles LS, Webster KE, McClelland JA, Cook J. Atrophy of the quadriceps is not isolated to the vastus medialis oblique in individuals with patellofemoral pain. J Orthop Sports Phys Ther. 2015;45(8):613-9. doi: 10.2519/jospt.2015.5852.
32. Raj IS, Bird SR, Shield AJ. Reliability of ultrasonographic measurement of the architecture of the vastus lateralis and gastrocnemius medialis muscles in older adults. Clin Physiol Funct Imaging. 2012;32(1):65-70. doi: 10.1111/j.1475-097X.2011.01056.x.
33. Lin YF, Lin JJ, Cheng CK, Lin DH, Jan MH. Association between sonographic morphology of vastus medialis obliquus and patellar alignment in patients with patellofemoral pain syndrome. J Orthop Sports Phys Ther. 2008;38(4):196-202. doi: 10.2519/jospt.2008.2568.
34. Jan MH, Lin DH, Lin JJ, Lin CH, Cheng CK, Lin YF. Differences in sonographic characteristics of the vastus medialis obliquus between patients with patellofemoral pain syndrome and healthy adults. Am J Sports Med. 2009;37(9):1743-9. doi: 10.1177/0363546509333483.
35. Ferreira de Meneses SR, Hunter DJ, Young Docko E, Pasqual Marques A. Effect of low-level laser therapy (904 nm) and static stretching in patients with knee osteoarthritis: a protocol of randomised controlled trial. BMC Musculoskelet Disord. 2015;16:252. doi: 10.1186/s12891-015-0709-9.
36. Astri SW, Murdhana N, Nusdwinuringtyas N, Kekalih A, Sunarjo P, Soewito F. The comparison of the low-level laser therapy and high intensity laser therapy on pain and functional ability in knee osteoarthritis. J Indones Med Assoc. 2023;72(6):275-83.
37. Wickenheisser VA, Zywot EM, Rabjohns EM, Lee HH, Lawrence DS, Tarrant TK. Laser light therapy in inflammatory, musculoskeletal, and autoimmune disease. Curr Allergy Asthma Rep. 2019;19(8):37. doi: 10.1007/s11882-019-0869-z.
38. de Matos Brunelli Braghin R, Libardi EC, Junqueira C, Rodrigues NC, Nogueira-Barbosa MH, Renno ACM, et al. The effect of low-level laser therapy and physical exercise on pain, stiffness, function, and spatiotemporal gait variables in subjects with bilateral knee osteoarthritis: a blind randomized clinical trial. Disabil Rehabil. 2019;41(26):3165-72. doi: 10.1080/09638288.2018.1493160.
39. Nambi G. Does low level laser therapy has effects on inflammatory biomarkers IL-1β, IL-6, TNF-α, and MMP-13 in osteoarthritis of rat models-a systemic review and meta-analysis. Lasers Med Sci. 2021;36(3):475-84. doi: 10.1007/s10103-020-03124-w.
40. Akaltun MS, Altindag O, Turan N, Gursoy S, Gur A. Efficacy of high intensity laser therapy in knee osteoarthritis: a double-blind controlled randomized study. Clin Rheumatol. 2021;40(5):1989-95. doi: 10.1007/s10067-020-05469-7.
41. Stausholm MB, Naterstad IF, Joensen J, Lopes-Martins RÁ, Sæbø H, Lund H, et al. Efficacy of low-level laser therapy on pain and disability in knee osteoarthritis: systematic review and meta-analysis of randomised placebo-controlled trials. BMJ Open. 2019;9(10):e031142. doi: 10.1136/bmjopen-2019-031142.
42. Gendy AE, Medhat A, Zikri EN, Abdel-Wahhab KG, Ibrahim FA, Shafei HF, et al. Evaluation of the efficiency of low-power laser shower in management of knee osteoarthritis. Comp Clin Path. 2024. doi: 10.1007/s00580-024-03602-5.
43. Elboim-Gabyzon M, Nahhas F. Laser therapy versus pulsed electromagnetic field therapy as treatment modalities for early knee osteoarthritis: a randomized controlled trial. BMC

Geriatr. 2023;23(1):144. doi: 10.1186/s12877-022-03568-5.

44. Youssef EF, Muaidi QI, Shanb AA. Effect of laser therapy on chronic osteoarthritis of the knee in older subjects. J Lasers Med Sci. 2016;7(2):112-9. doi: 10.15171/jlms.2016.19.
45. Liebert A, Capon W, Pang V, Vila D, Bicknell B, McLachlan C, et al. Photophysical mechanisms of photobiomodulation therapy as precision medicine. Biomedicines. 2023;11(2):237. doi: 10.3390/biomedicines11020237.
46. Alfredo PP, Bjordal JM, Dreyer SH, Meneses SR, Zaguetti G, Ovanessian V, et al. Efficacy of low-level laser therapy associated with exercises in knee osteoarthritis: a randomized double-blind study. Clin Rehabil. 2012;26(6):523-33. doi: 10.1177/0269215511425962.
47. Li BM, Zhang CK, He JH, Liu YQ, Bao XY, Li FH. The effects of photobiomodulation on knee function, pain, and exercise tolerance in older adults: a meta-analysis of randomized controlled trials. Arch Phys Med Rehabil. 2024;105(3):593-603. doi: 10.1016/j.apmr.2023.06.016.
48. Rahmati M, Gondin J, Malakoutinia F. Effects of neuromuscular electrical stimulation on quadriceps muscle strength and mass in healthy young and older adults: a scoping review. Phys Ther. 2021;101(9):pzab144. doi: 10.1093/ptj/pzab144.
49. Ahmad MA, Moganan M, Hamid MS, Sulaiman N, Moorthy U, Hasnan N, et al. Comparison between low-level and high-intensity laser therapy as an adjunctive treatment for knee osteoarthritis: a randomized, double-blind clinical trial. Life (Basel). 2023;13(7):1519. doi: 10.3390/life13071519.