Observational study

Clin Ter 2025; 176 (3):330-335 doi: 10.7417/CT.2025.5230

The effects of laser therapy on pain, functionality and biomechanical parameters in patients suffering from gonarthrosis: an observational study

F. Agostini[1], F. Capuano[1], C. Sebastiani[1], V. Santilli[1], G. Santilli[2], M. Damanti[1], M. Isola[1], M. Paoloni[1], M. Mangone[1]

[1] Department of Anatomy, Histology, Forensic Medicine and Orthopedics, Sapienza University, Rome, Italy; [2] Department of Surgical and Medical Sciences and Translational Medicine, Sapienza University of Rome, Rome, Italy

Abstract

Background. Knee osteoarthritis (KOA) consists of a heterogeneous pathology of the peripheral joints, characterized by a complex, multifactorial nature and with multiple risk factors. The aim of this study was to evaluate the effects of laser therapy on pain and biomechanical parameters in patients with KOA.

Methods. A retrospective study was carried out for patients with KOA (I-II Kellgren-Lawrence). All patients underwent 10 sessions of Laser therapy (three/week). Patients were evaluated at T0 and 22 days later-T1. At T0, before the treatment and at T1 pain (Visual Analogue Scale-VAS), symptoms (Knee Injury and Osteoarthritis Outcome Score-KOOS and Western Ontario and McMaster Universities Osteoarthritis Index-WOMAC) and instrumental assessment (gait analysis) were assessed.

Results. Twelve patients were included. A significant difference was found in all three scales between T0-T1, VAS decreased by three points (p=0.002), KOOS increased by fifteen points (p=0.008) and WOMAC decreased by 8.5 (p=0.003). For gait analysis parameters, we detected a significant decrease in stance duration (p=0.04), a marked increase in speed normalized to height (p=0.01), an increase in knee ROM (p=0.01) and an increase in maximum knee moment (p=0.02).

Conclusions. Laser therapy is an effective intervention in the management of KOA. Our study showed that laser therapy is effective in relieving pain and improving symptoms as well as gait parameters.
Clin Ter 2025; 176 (3):330-335 doi: 10.7417/CT.2025.5230

Keywords: *laser therapy; rehabilitation; pain; gonarthrosis; gait analysis*

Background

Osteoarthrosis is a degenerative disease in which the loss of cartilage causes alterations in the adjacent bone and its response produces deformations and attempts at regeneration (1). Knee osteoarthritis (KOA) consists of a heterogeneous pathology of the peripheral joints, characterized by a complex, multifactorial nature and with multiple risk factors. The risk factors can be divided into modifiable ones, such as obesity or the habit of smoking, and not modifiable ones, such as age, female sex and genetic predisposition (2). The degenerative disease occurs in the advanced stages of life and clinically manifests itself with pain, muscle weakness, deformity, and limitation of joint mobility with consequent loss of functionality, increased disability, lower performance in activities of daily living. Furthermore, it causes significant involutional changes of the articular hyaline cartilage (3, 4). The articular cartilage goes through deterioration and breakdown, accompanied by inflammation of the synovial membrane, decrease in the intra-articular space and sclerosis of the subchondral bone. Knee deformities in patients suffering from primary KOA are numerous with bone and soft tissue causes that justify the presence of these deformities (5). To determine the extent of KOA, radiographs can be examined according to the Kellgren and Lawrence Grading System (KL, from I to IV) (6). Treatment of KOA can be divided into non-surgical or surgical treatment. Non-surgical treatment comprises non-pharmacological and pharmacological treatment, and non-pharmacological treatment comprises core first-line treatment for all patients with OA, including education, self-management, exercise, and weight reduction. Other primary non-pharmacological treatments for KOA include walking canes and biomechanical interventions like braces and orthosis. Pharmacological therapy may include the use of paracetamol, topical or oral non-steroidal anti-inflammatory drugs (NSAIDs), or intra-articular corticosteroids. Surgical procedures are a last resort for end-stage KOA, the most effective type of which is total knee arthroplasty with rehabilitation (7). Currently, no treatment can alter the course of OA, and therapy is directed at reducing pain and improving function. Medications, including NSAIDs, acetaminophen, duloxetine, opioids, topical NSAIDs, and capsaicin, are effective in reducing symptoms. Intra-articular injections are usually carried out using corticosteroid, hyaluronic acid (HA), ozone, plasma rich in growth factor, and platelet-rich plasma (8).

Correspondence: Francesco Agostini, Department of Anatomy, Histology, Forensic Medicine, and Orthopedics, Sapienza University, Piazzale Aldo Moro 5, 00185 Rome, Italy. Tel.: +39 3404751090. e-mail: francesco.agostini@uniroma1.it

ISSN 1972-6007

Several adjunct therapies are used as complements to core KOA treatments with the goal of maximizing outcomes for patients. Thermal modalities (such as cold and heat), laser therapy, therapeutic ultrasound, electrical stimulation, manual therapy techniques, taping, acupuncture, among others, are some interventions that are commonly used (9). Some studies also show that training with WBV (whole-body vibration) reduces pain and improves function in individuals with KOA (10). Laser (an acronym for "Light Amplification by Stimulated Emission of Radiation") therapy can be used to relieve the pain related to this condition, which greatly impairs the patient's physical comfort and limits physical activity (11). The main indications of laser therapy in Rehabilitation Medicine include the treatment of patients affected of: osteoarthritis in the painful exacerbation phase, tendinopathies and enthesopathies in various regions and of various types (tendinitis, peri-tendinitis, tenosynovitis, insertional and calcific tendinitis, tendinosis, partial tendon injuries), bursitis and capsulitis, inflammatory arthropathies in rheumatic diseases, vertebral pains, post-traumatic oedemas and hematomas, joint sprain and contusion outcomes, muscle contractures and injuries, periostitis, degenerative and post-traumatic chondropathies, meniscopathies and synovitis, functional overload/overuse pathologies in sportsmen and women, painful arthroplasty without septic or aseptic mobilization or instability of prosthetic components (11-14). Laser therapy exploits the biological effects of nonionizing electromagnetic radiation produced by devices that amplify light waves and emit monochromatic, coherent, one-way, high-brightness light beams (11). The effect of this therapy is photochemical and not thermal. Light triggers biochemical changes in cells. The biological effects of laser therapy are the result of different types of interactions that can be photochemical, photothermal and photomechanical. The photochemical effects, which largely depend on the wavelength and delivery modality of the emitted radiation, are responsible for the activation of cell metabolic turnover at skin and subcutaneous level, promoting various enzymatic reactions of protein and nucleic acid synthesis; furthermore, this type of photochemical interaction is also important in the anti-inflammatory and anti-edematous effects. The photothermal effects, determined by the increase in temperature due to the conversion of light energy into thermal energy up to a temperature of 42°C, determine a tissue heating promoting important biological effects such as: reduction of muscle spasm, increased elasticity of capsules and ligaments and direct and indirect analgesic effects. Finally, it is also possible to obtain a photomechanical effect through the interaction between a high-energy light pulse and a physical medium, which is useful in the treatment of various diseases (15, 16). The parameters defining the cells' effects are irradiation/power (W/cm^2), energy density (J/cm^3) and time (sec); these parameters are selected on the basis of the desired inhibitory or stimulatory effect. The actual energy density administered depends on the tissue's ability to penetrate, or the possibility of reaching the target cells, and two other parameters come into play: wavelength (absorption and transmission of the different tissues) and mode of administration (in relation to the depth of the area). Laser therapy has evidence of proven efficacy in the treatment of KOA related pain, with effects on reducing this symptom, improving joint function in terms of increasing joint ROM, and reducing stiffness (17-21). The aim of this study was to evaluate the effects of laser therapy on pain and biomechanical parameters in patients with KOA.

Materials and methods

A retrospective study was carried out for patients with medical and radiological diagnosis of KOA (I-II KL), who referred to the physical medicine and rehabilitation Unit of the University Hospital Umberto I of Rome in the period November-January 2024.

Inclusion and exclusion criteria

The inclusion criteria were ages between 35 and 65 and the presence of significant knee pain that invalidated the quality of their lives, during daily living activities, such as: descending/ ascending stairs, rising from bed, lying in bed, getting in/out of bath, etc. and pain VAS >3/10.

Patients with secondary knee pain and that had received local infiltrations in the last 4 months, who underwent lower limb surgery and patients with diabetes, systemic rheumatic disease, recent myocardial infarctions and cerebrovascular accidents, cognitive impairment/psychiatric disorders (Mini-Mental State Examination <24), oncological and nervous diseases were excluded from the study. Patients with contraindications to the use of instrumental physical therapy such as tumors, infections in the segment to be treated, cardiac pacemaker and pregnant women, were excluded as well.

Interventions

After enrollment, all patients underwent 10 sessions of Laser therapy (qmd® Helios laser, Hakomed Italia Srl, Egna, Bolzano), three sessions a week with one day from each other. Patients were positioned on a chair, with knees flexed to 90° on a small step while a doctor specialist in physical and rehabilitation medicine and expert in laser therapy carried out the treatment. The sessions were carried out using the laser "anti-inflammatory effect" program which includes the 1064 nm (nanometers) wavelength, which is known for its pain-reducing effect; the 1120 nm wavelength, which has been shown to have the same absorption spectrum as serotonin, dopamine and histamine, and is therefore expected to have a particularly good anti-inflammatory effect (22-25); and the wavelength 808 nm to exploit only its anti-inflammatory and biostimulatory power in depth. We have a continuous delivery modality, a pulsed modality with a fixed frequency and a frequency scanning phase (harmonic pulsation®), from a pulsed delivery modality able to regulate healing processes in a global way and able to guarantee the widest spectrum of biological effects. During the scan, the stimulation parameters vary continuously in order to optimize the relationship between stimulus duration and intensity. Scanning is included in all therapy schemes for its effectiveness and versatility.

Evaluations

Patients included in the study were evaluated at baseline (T0) and at the end of treatment (22 days later- T1). At T0, before the start of laser treatment and at T1 pain (Visual Analogue Scale-VAS), symptoms at the knee joint (Knee Injury and Osteoarthritis Outcome Score-KOOS), pain, stiffness, function (Western Ontario and McMaster Universities Osteoarthritis Index-WOMAC) and instrumental assessment of movement (gait analysis) were assessed.

Visual Analogue Scale

The Visual Analogue Scale (VAS) is one of the main tools for measuring the intensity of symptoms. Simply, the scale is made up of a 10 cm line of paper which has "end points" at both ends which define "no pain" and "most intense pain imaginable". The healthcare professional asks the patient to mark, with a line, a point on the scale that represents the pain as it is perceived at that moment. The interval between the two extreme points is marked every centimeter and allows a value to be attributed to the subjective pain perceived by the patient (26, 27).

Knee Injury and Osteoarthritis Outcome Score

The Knee Injury and Osteoarthritis Outcome Score (KOOS) measures patients' opinions about their knee and associated problems. It includes five domains: 1) frequency and severity of pain during activity; 2) symptoms such as the severity of knee stiffness and the presence of swelling, presence of noises such as grinding or clicking, sensations of entrapment, and limitation of movement; 3) difficulty experienced during activities of daily living (ADL); 4) difficulties encountered in sporting and recreational activities; and 5) quality of life (QOL). There are 42 items divided into 5 subscales. All items are rated on a 5-point scale (0–4), specific to each item. The 5 dimensions are evaluated separately as the sum of all the corresponding elements. The scores are then transformed into a scale of 0 to 100 (percentage of total possible score achieved), where 0 = extreme knee problems and 100 = no knee problems (28, 29).

Western Ontario and McMaster Universities Osteoarthritis Index

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is a specific measure of osteoarthritis (OA) symptoms (pain and stiffness) and functional deterioration of the knee that is routinely used in clinical trials (30). This scale is composed of 24 items divided into 3 subscales: pain (5 items), stiffness (2 items) and physical function (17 items). Questions were scored on a scale of 0 to 4, corresponding to none (0), mild (1), moderate (2), severe (3) and extreme (4). The score for each subscale is summarized with a score range of 0 to 20 for pain, 0 to 8 for stiffness, and 0 to 68 for physical function. The sum of all three scores gives the total WOMAC score value (31).

Gait Analysis

Instrumental movement assessment currently represents an indispensable analysis for the biomedical sector to evaluate objectively and accurately human movement and human posture (32). Biomechanical characteristics of movement, spatial-temporal, kinematic, kinetic and surface electromyography, as well as characteristics of their variations from a normal situation, have an important impact on diagnosis of neurological and muscular pathologies. Furthermore, they have a significant impact on prognosis, therapeutic approach and follow-up. Now, the most popular devices for the assessment of movement, and in particular of gait, together with the clinician's evaluation, are video-motion analysis systems. Motion analysis provides the clinician with quantitative, three-dimensional, kinematic, kinetic and muscle activation information (33). For this study SMART-DX 4000, an extremely versatile system that is well able to meet all analysis laboratory demands, both in routine use, typical of the clinical field, and in experimental use under the scope of sport and research, was used. SMART-DX 4000 is based on new-designed digital video cameras that use highly sensitive sensors and innovative, functional illuminators whose high radiation power, combined with the high resolution of the video camera (up to 2,4 Megapixels), increases the working volume and allows for capturing extremely rapid and imperceptible movements. SMART-DX 4000 represents an evolutionary leap in the development of multifactorial motion analysis, now made more accurate, integrated, quicker and more productive. The system integrates, synchronizes and manages all kinematic, kinetic, electromyographic and video data in real time as it is obtained from connected devices such as force platforms, electromyographs, sensor-fitted treadmills, etc. The system has the following features: sensor resolution 1936x1216 (2,4 Mpixel), acquisition frequency at maximum resolution (160 fps), Accuracy <0,1mm on a volume 4x4x3m.

Statistical analysis

Statistical analysis was conducted using IBM SPSS (version 27) software to evaluate pre- and post-treatment differences in gait analysis parameters. The non-parametric Wilcoxon test was used, and the results are represented in terms of median and range of variation (min-max). As regards the evaluation of the differences in the VAS, KOOS and WOMAC scales, the non-parametric Wilcoxon test was used, and the results are represented in terms of median and range of variation (min-max).

Results

Twelve patients who met the inclusion and exclusion criteria were included (table 1). As regards the evaluation scales, a significant difference was found in all three scales, in particular the VAS decreased by three points between T0 and T1 (p=0.002), the KOOS increased by fifteen points between T0 and T1 (p=0.008) and WOMAC decreased by 8.5 points between T0 and T1 (p=0.003) (table 2). As re-

Table 1. Characteristics of the patients.

Age	52,16667 ± 15,23652
Sex	6M - 6F
Height	165,1667 ± 10,38209
Weight	67,33333 ± 10,7647

Table 2. Evaluation scale.

Scale	T0	T1	p value
VAS	6 (3-10)	3 (2-7)	0.002*
KOOS	53 (18-84)	68 (28-86)	0.008*
WOMAC	23.5 (10-68)	15 (2-57)	0.003*

VAS: The Visual Analogue Scale; KOSS: The Knee Injury and Osteoarthritis Outcome Score; WOMAC: The Western Ontario and McMaster Universities Osteoarthritis Index;
*: Statistical significance.

gards the gait analysis parameters, we detected a significant decrease in stance duration (p=0.04), a marked increase in speed normalized to height (p=0.01), an increase in knee ROM (p=0.01) and an increase in maximum knee moment (p=0.02) (table 3).

Discussion

The aim of our study was to investigate the usefulness of laser therapy in patients suffering from KOA, considering both the improvement of symptoms in daily life activities and the improvement of the parameters investigated with gait analysis. The results of this study show that the use of laser therapy is effective in relieving pain, assessed using a VAS scale, in improving patient's symptoms and related problems measured with KOOS scale and in improving osteoarthritis symptoms evaluated through the WOMAC scale. Moreover, this study shows that after 10 sessions of laser therapy, significant improvements occur as far as is concerned gait analysis parameters. An increase in speed was in fact detected during walking and an improvement in maximum knee moment and in knee ROM. Furthermore, a significant decrease in stance duration was found. These results demonstrate that laser therapy treatment guarantees rapid results in reducing pain and improving walking. In 2012, Gworys et al., conducted a random study in order to estimate the influence of various laser therapy methods on knee joint pain and function in patients with KOA. The author concluded that one-wave laser irradiation at a dose of 8 J per point and two-wave laser irradiation with doses of 12.4 J and 6.6 J per point significantly improved knee joint function and relieved knee pain in patients with osteoarthritis (34). In 2013, Alves and colleagues, used a rat model of osteoarthritis produced by intra-articular injection of the cartilage-degrading enzyme papain to test 810-nm laser therapy. A single application of laser therapy produced significant reductions in inflammatory cell infiltration and inflammatory cytokines 24 hours later. A lower laser power was more effective than a higher laser power (35).

In 2016, Tomazoni et al., in order to highlight which were the most effective therapeutic interventions between a topical NSAID, physical activity, and photo biomodulation therapy (PBMT) applied alone and/or in combination between them in an experimental model of KOA (OA was induced by injection of papain in the knees of rats and after 21 days, the animals started to be treated with the above treatment). The results demonstrate that PBMT and NSAID reduce the total number of cells in the inflammatory infiltrate and PBMT was the most effective for reducing the activity of

Table 3. Gait parameters.

Gait parameters	T0	T1	p value
Stride duration (s)	1.29 (1.12-1.41)	1.26 (1.07-1.41)	0.05
Stance duration (s)	0.78 (0.66-0.91)	0.76 (0.64-0.91)	0.04*
Swing duration (s)	0.50 (0.46-0.52)	0.48 (0.42-0.62)	0.38
Stance duration (%)	61.09 (58.17-64.71)	62.17 (52.76-64.49)	0.64
Swing duration (%)	38.91 (35.23-41.83)	37.83 (35.51-47.24)	0.55
Single limb stance duration (%)	40.13 (36.78-48.01)	40.88 (37.72-44.09)	0.92
Double support duration (%)	11.42 (6.49-15.01)	9.13 (1.53-14.20)	0.07
Stride length (m)	1.085 (0.81-1.46)	1.15 (0.82-1.50)	0.1
Stride length normalized to height (%)	64.88 (52.91-83.53)	68.19 (49.74-85.77)	0.27
Step length (m)	0.51 (0.41-0.75)	0.55 (0.31-0.76)	0.55
Speed normalized to height (%)	49.25 (36.66-69.45)	53.41 (36.63-74.17)	0.01*
Cadence (steps/min)	92.70 (81.60-117.30)	94.50 (84-115.20)	0.13
Step width (m)	0.080 (0.06-0.61)	0.08 (0.05-0.16)	0.97
Flexion-extension RoM (°)	50.60 (37.20-64.70)	54.20 (40.40-66.90)	0.01*
Knee flexion at loading response (°)	21.70 (-15.3-42.60)	21.95 (-10.70-31.20)	0.43
Maximum knee moment (N*m/Kg)	0.075 (0.054-0.092)	0.21 (0.04-0.388)	0.02*

S: seconds; %: percentage; m: meters; min: minutes;
°: degrees; N: Newton; Kg: kilograms: Rom: Range of Motion;
*: Statistical significance.

myeloperoxidase. Finally, they observed that both NSAID and PBMT were effective for reducing the gene expression of matrix metalloproteinase-3 (MMP), but in relation to the gene expression of MMP-13, PBMT was the most effective treatment (36). In 2017, Rayegani et al., conducted a meta-analysis with the aim of determine the safety and efficacy of laser therapy in patients with KOA. The authors concluded that there was a significant difference between laser therapy and placebo in pain at rest, pain at activity, total pain, WOMAC function, WOMAC stiffness and WOMAC total in favor of the laser therapy (19). In 2019, Stausholm et al., conducted a systematic review and meta-analysis with the aim of studying the effects of laser therapy in KOA. The authors concluded that laser therapy reduces pain and disability in KOA at 4-8 J with 785-860 nm wavelength and at 1-3 J with 904 nm wavelength per treatment spot (20). In 2023, Malik et al., conducted a systematic review and meta-analysis to investigate the effectiveness of laser therapy plus exercise therapy (ET) on pain, ROM, muscle strength, and function in KOA immediately after therapy and whether the effectiveness of laser therapy plus ET could be sustained at follow-up (4 - 32 weeks). The findings of this study indicate that laser therapy plus ET could be considered to alleviate pain in the KOA. Laser therapy reduces pain at 4-8J with a wavelength of 640-905nm per point applied for 10-16 sessions at a frequency of 2 sessions/week. An exercise therapy program at prescribed dosage involving major muscle groups might help. However, laser therapy plus ET is no more effective than placebo laser therapy plus ET in improving ROM, muscle strength, and function in KOA (37).

Laser therapy is now widely used as a therapeutic and rehabilitative treatment in many pathologies of the musculoskeletal system with analgesic and anti-inflammatory purposes. The most frequently studied pathologies are osteoarthritis in the painful exacerbation phase, tendinopathies and enthesopathies, bursitis and capsulitis, inflammatory arthropathies in rheumatic diseases, post-traumatic oedemas and hematomas. The purpose of using laser is to improve pain and inflammatory symptoms and, due to its feasibility, it is widely used. Our study and the resulting data are consistent with those currently present in the literature which highlight a reduction in pain and an improvement in daily living activities after a cycle of laser therapy.

Limitations

Certainly, our study is not without limitations. The small number of samples and a longer-term follow-up certainly represent a limitation. In addition, patients have different degrees of severity of tendinopathies, and possible reintroduction of sports activity was not considered in the evaluation.

Conclusions

Laser therapy is an effective intervention in the management of KOA. In fact, our study showed that laser therapy in KOA is effective in relieving pain and improving symptoms as well as improving walking. More future studies with a higher number of patients and longer follow-up are needed to better quantify the effects of the laser on these types of patients.

Funding: No founds

Conflict of interest: Authors report no conflict of interest.

References

1. Jiang Y. Osteoarthritis year in review 2021: biology. Osteoarthritis Cartilage. 2022 Feb;30(2):207-215. doi: 10.1016/j.joca.2021.11.009..
2. Bernetti A, Agostini F, Paoloni M, et al. Could Hyaluronic Acid Be Considered as a Senomorphic Agent in Knee Osteoarthritis? A Systematic Review. Biomedicines. 2023 Oct 22;11(10):2858. doi: 10.3390/biomedicines11102858.
3. Abramoff B, Caldera FE. Osteoarthritis: Pathology, Diagnosis, and Treatment Options. Med Clin North Am. 2020 Mar;104(2):293-311. doi: 10.1016/j.mcna.2019.10.007.
4. Barnett R. Osteoarthritis. Lancet. 2018 May 19; 391(10134):1985. doi: 10.1016/S0140-6736(18)31064-X
5. Bernetti A, Agostini F, Alviti F, et al. New Viscoelastic Hydrogel Hymovis MO.RE. Single Intra-articular Injection for the Treatment of Knee Osteoarthritis in Sportsmen: Safety and Efficacy Study Results. Front Pharmacol. 2021 May 28;12:673988. doi: 10.3389/fphar.2021.673988.
6. Kohn MD, Sassoon AA, Fernando ND. Classifications in Brief: Kellgren-Lawrence Classification of Osteoarthritis. Clin Orthop Relat Res. 2016 Aug;474(8):1886-93. doi: 10.1007/s11999-016-4732-4. Epub 2016 Feb 12.
7. Kan HS, Chan PK, Chiu KY, et al. Non-surgical treatment of knee osteoarthritis. Hong Kong Med J. 2019 Apr;25(2):127-133. doi: 10.12809/hkmj187600.
8. Perruccio AV, Young JJ, Wilfong JM, et al. Osteoarthritis year in review 2023: Epidemiology & therapy. Osteoarthritis Cartilage. 2024 Feb;32(2):159-165. doi: 10.1016/j.joca.2023.11.012.
9. Dantas LO, Salvini TF, McAlindon TE. Knee osteoarthritis: key treatments and implications for physical therapy. Braz J Phys Ther. 2021 Mar-Apr;25(2):135-146. doi: 10.1016/j.bjpt.2020.08.004. Epub 2020 Sep 8.
10. Zafar H, Alghadir A, Anwer S, et al. Therapeutic effects of whole-body vibration training in knee osteoarthritis: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2015 Aug;96(8):1525-32. doi: 10.1016/j.apmr.2015.03.010.
11. Ahmad MA, A Hamid MS, Yusof A. Effects of low-level and high-intensity laser therapy as adjunctive to rehabilitation exercise on pain, stiffness and function in knee osteoarthritis: a systematic review and meta-analysis. Physiotherapy. 2022 Mar;114:85-95. doi: 10.1016/j.physio.2021.03.011.
12. Cameron MH, Physical Agents in Rehabilitation: An Evidence-Based Approach to Practice, E Book, V ed., Elsevier, 2017.
13. Medeiros DM, Aimi M, Vaz MA, et al. Effects of low-level laser therapy on hamstring strain injury rehabilitation: A randomized controlled trial. Phys Ther Sport. 2020 Mar;42:124-130. doi: 10.1016/j.ptsp.2020.01.006.
14. Zati A, Valent A. Terapia fisica. Nuove tecnologie in medicina riabilitativa, 2° Ed, Minerva Medica, 2017.
15. Paolillo FR, Paolillo AR, João JP, et al. Ultrasound plus low-level laser therapy for knee osteoarthritis rehabilitation:

a randomized, placebo-controlled trial. Rheumatol Int. 2018 May;38(5):785-793. doi: 10.1007/s00296-018-4000-x.
16. Zati A, Desando G, Cavallo C, et al. Treatment of human cartilage defects by means of Nd:YAG Laser Therapy. J Biol Regul Homeost Agents. 2012 Oct-Dec;26(4):701-11.
17. Moskvin S, Askhadulin E, Kochetkov A. Low-Level Laser Therapy in Prevention of the Development of Endothelial Dysfunction and Clinical Experience of Treatment and Rehabilitation of COVID-19 Patients. Rehabil Res Pract. 2021 Jan 26;2021:6626932. doi: 10.1155/2021/6626932.
18. Clijsen R, Brunner A, Barbero M, et al. Effects of low-level laser therapy on pain in patients with musculoskeletal disorders: a systematic review and meta-analysis. Eur J Phys Rehabil Med. 2017 Aug;53(4):603-610. doi: 10.23736/S1973-9087.17.04432-X.
19. Rayegani SM, Raeissadat SA, Heidari S, et al. Safety and Effectiveness of Low-Level Laser Therapy in Patients With Knee Osteoarthritis: A Systematic Review and Meta-analysis. J Lasers Med Sci. 2017 Summer;8(Suppl 1):S12-S19. doi: 10.15171/jlms.2017.s3. Epub 2017 Aug 29.
20. Stausholm MB, Naterstad IF, Joensen J, 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 Oct 28;9(10):e031142. doi: 10.1136/bmjopen-2019-031142.
21. Gendron DJ, Hamblin MR. Applications of Photobiomodulation Therapy to Musculoskeletal Disorders and Osteoarthritis with Particular Relevance to Canada. Photobiomodul Photomed Laser Surg. 2019 Jul;37(7):408-420. doi: 10.1089/photob.2018.4597.
22. Choo LP, Jackson M, Mantsch HH. Conformation and self-association of the peptide hormone substance P: Fourier-transform infrared spectroscopic study. Biochem J. 1994 Aug 1;301 (Pt 3)(Pt 3):667-70. doi: 10.1042/bj3010667.
23. Lagutschenkov A, Langer J, Berden G, et al. Infrared spectra of the protonated neurotransmitter histamine: competition between imidazolium and ammonium isomers in the gas phase. Phys Chem Chem Phys. 2011 Sep 14;13(34):15644-56. doi: 10.1039/c1cp21681c.
24. Lagutschenkov A, Langer J, Berden G, et al. Infrared spectra of protonated neurotransmitters: dopamine. Phys Chem Chem Phys. 2011 Feb 21;13(7):2815-23. doi: 10.1039/c0cp02133d.
25. Lagutschenkov A, Langer J, Berden G, et al. Infrared spectra of protonated neurotransmitters: dopamine. Phys Chem Chem Phys. 2011 Feb 21;13(7):2815-23. doi: 10.1039/c0cp02133d.
26. Sung YT, Wu JS. The Visual Analogue Scale for Rating, Ranking and Paired-Comparison (VAS-RRP): A new technique for psychological measurement. Behav Res Methods. 2018 Aug;50(4):1694-1715. doi: 10.3758/s13428-018-1041-8.
27. Paolucci T, Bernetti A, Paoloni M, et al. Therapeutic Alliance in a Single Versus Group Rehabilitative Setting After Breast Cancer Surgery: Psychological Profile and Performance Rehabilitation. Biores Open Access. 2019 Jul 3;8(1):101-110.
28. Collins NJ, Misra D, Felson DT, et al. Measures of knee function: International Knee DocumentationCommittee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale,Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index(WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). Arthritis Care Res(Hoboken). 2011 Nov;63 Suppl 11(0 11):S208-28. doi: 10.1002/acr.20632.
29. Roos EM, Roos HP, Lohmander LS, et al. Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. J Orthop Sports Phys Ther. 1998 Aug;28(2):88-96. doi: 10.2519/jospt.1998.28.2.88.
30. Conaghan PG, Dworkin RH, Schnitzer TJ, et al. WOMAC Meaningful Within-patient Change: Results From 3 Studies of Tanezumab in Patients With Moderate-to-severe Osteoarthritis of the Hip or Knee. J Rheumatol. 2022 Jun;49(6):615-621. doi: 10.3899/jrheum.210543.
31. Singhal S, Hasan N, Nirmal K, et al. Bioavailable turmeric extract for knee osteoarthritis: a randomized, non-inferiority trial versus paracetamol. Trials. 2021 Jan 30;22(1):105. doi: 10.1186/s13063-021-05053-7.
32. Baker R, McGinley JL, Schwartz MH, et al. The gait profile score and movement analysis profile. Gait Posture. 2009 Oct;30(3):265-9. doi:10.1016/j.gaitpost.2009.05.020. Epub 2009 Jul 24.
33. Schwartz MH, Rozumalski A. The Gait Deviation Index: a new comprehensive index of gait pathology. Gait Posture. 2008 Oct;28(3):351-7. doi: 10.1016/j.gaitpost.2008.05.001. Epub 2008 Jun 18.
34. Gworys K, Gasztych J, Puzder A, et al. Influence of various laser therapy methods on knee joint pain and function in patients with knee osteoarthritis. Ortop Traumatol Rehabil. 2012 May-Jun;14(3):269-77. English, Polish. doi: 10.5604/15093492.1002257.
35. Hamblin MR. Can osteoarthritis be treated with light? Arthritis Res Ther. 2013 Oct 29;15(5):120. doi: 10.1186/ar4354.
36. Tomazoni SS, Leal-Junior EC, Frigo L, et al. Isolated and combined effects of photobiomodulation therapy, topical nonsteroidal anti-inflammatory drugs, and physical activity in the treatment of osteoarthritis induced by papain. J Biomed Opt. 2016 Oct 1;21(10):108001. doi: 10.1117/1.JBO.21.10.108001.
37. Malik S, Sharma S, Dutta N, et al. 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 Mar;40(1):8-24. doi: 10.1080/08990220.2022.2157387.