



The Immediate, Short-Term and Long-Term Effects of Photobiomodulation on Chronic Post-Surgical Pain After Tympanomastoidectomy Surgery

Shadman Nemati¹ , Kamran Ezzati^{2*} , Ali Faghih Habibi¹, Maryam Shakiba³, Shadi Salamroudi¹, Hedieh Ramezani¹

¹Otorhinolaryngology Research Center, Department of Otolaryngology and Head and Neck Surgery, School of Medicine, Amiralmomenin Hospital, Guilan University of Medical Sciences, Rasht, Iran

²Trauma Institute, Neuroscience Research Center, Poorsina Hospital, Department of Physiotherapy, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran

³Department of Biostatistics and Epidemiology, School of Health, Guilan University of Medical Sciences, Rasht, Iran

*Correspondence to
Kamran Ezzati,
Email: Ez_kamran@yahoo.com

Received: May 19, 2025
Accepted: November 22, 2025
ePublished: June 7, 2026

Abstract

Introduction: Photobiomodulation (PBM) is one of the alternatives to opioid analgesics to reduce post-operative pain. The aim of this study was to investigate the immediate, short-term, and long-term effects of PBM on chronic post-surgical pain after tympanomastoidectomy.

Methods: A total of 138 subjects who had undergone tympanomastoidectomy were selected randomly and divided into two groups: PBM and control. Patients in the PBM group (n=64) received laser therapy (energy density of 8 J/cm², wavelength of 980 nm, and power of 50 mW in 8 points behind the ear during ten sessions every day) with routine drug therapy, while patients in the control group (n=64) received only routine drug therapy (Dexamethasone, cephalexin 500 mg, acetaminophen 500 mg). The visual analogue scale (VAS) and the headache subscale of the neck disability index (NDI) were provided to both groups to assess pain intensity before the intervention, after sessions one and five, and at one- and three-month follow-ups. The between-group comparison was made through the Mann-Whitney U test, and the within-group comparison was performed using the Friedman test with pairwise comparisons.

Results: No significant differences in all variables were observed between the two groups at baseline ($P > 0.05$). The between-group comparison showed significantly lower VAS scores in PBM compared to the control group at all four time points of the study, resulting in a very large effect size at session 5, month 1, and month 3. Also, the PBM group had significantly lower NDI scores at session 5, month 1, and month 3 ($P < 0.001$). The effect size was large at session 5 and very large thereafter.

Conclusion: The combined effects of PBM and drugs may reduce pain intensity in short-term and long-term follow-ups in patients after tympanomastoidectomy. Nevertheless, PBM did not show immediate effects on pain.

The trial registration number: IRCT200808310011138N28

Keywords: Surgery, Pain, Laser therapy, Photobiomodulation



Introduction

Post-operative pain is one of the major challenges today.^{1,2} During the first few days after the surgery, the incidence of acute neuropathic pain is 2 to 3%, and pain lasting more than three months is considered chronic, with an incidence of approximately 10% after surgery.^{1,2} There are many reports about the amount of persistent pain in different types of surgeries.² In one study, the prevalence of chronic pain at the mastoidectomy incision site was 32.3 %, and although the average pain intensity was not severe, it was frequently associated with some degree of disability and sleep disturbances.³ Also, post-operative pain after tympanomastoidectomy is prevalent, and some factors such as age, comorbidities, revision surgery, dizziness

and tinnitus may affect its severity.⁴ Various drugs and techniques are used to control post-operative pain.^{1,5} In recent years, photobiomodulation (PBM), or low-level laser therapy, has been recognized as one of the alternatives to opioid analgesics for reducing post-operative pain and facilitating a return to normal function.^{6,7} It has been revealed that PBM could treat chronic infection of the middle ear and mastoid at the same time and improve hearing loss after tympanomastoidectomy.^{8,9} Furthermore, PBM is known as a safe method for reducing pain and inflammation and can accelerate the recovery of soft tissues.¹⁰ In addition, PBM with photo-chemical effects may reduce inflammation quickly by affecting blood flow and cellular functions.¹¹

Many studies have confirmed the analgesic efficacy of PBM after different post-surgical conditions.^{7,12} The effectiveness, protocols and follow-ups of PBM vary depending on the condition.⁷ On the other hand, considering the vital role of tympanomastoidectomy to improve middle ear disorders, there is no research on the combined effects of PBM and drugs to decrease postoperative pain in this field.¹³ In the present study, we investigated the immediate, short-term and long-term effects of PBM and drug therapy on post-operative pain after tympanomastoidectomy.

Method and Materials

The present study was a randomized, single-blinded clinical trial that was registered with the Iranian Clinical Trials Registration Center (IRCT20080831001138N28). The allocation ratio was 1:1. The Ethics Committee of Guilan University of Medical Sciences approved the study (IR.GUMS.REC.1397.159), and all patients accepted the items of the consent form. The sample size was obtained based on the previous study, in which an effect size of 89% in the intervention group and 66% in the control group, considering a type I error of 5% and a power of 80%, including a 20% dropout rate, resulted in a number of 64 people in each group.¹⁴ The inclusion criteria were as follows: patients suffering from tumors and malignancies that underwent tympanomastoidectomy surgery; age between 20–60 years old. Patients suffering from Bell's palsy and trigeminal neuralgia were excluded from the study. Of 138 subjects who had undergone tympanomastoidectomy and were screened for eligibility, 10 were excluded: 8 did not meet the inclusion criteria, and 2 declined to participate. Finally, 64 subjects were randomly enrolled in each group (G1 and G2). The subjects were candidates for tympanomastoidectomy at Amir-Al-Momenin University Hospital. Tympanomastoidectomy was performed by one skilled attendant surgeon (SN), with an incision behind the ear. After the mastoid bone exposure, it was removed by cortical excision, considering surgical landmarks and trying not to enter the critical anatomic adjacent spaces, such as the Fallopian canal, skull, and cochlea.^{3,15} Patients were randomly divided into two groups: PBM group (G1) and control group (G2). Randomization was performed using a random number table, with even numbers in the PBM group and odd numbers in the control group. The examiner and statistical analyzer were blinded. Patients in G1 received a low-level laser therapy using a Lasermed 4098 device (CARCI, Brazil). The treatment parameters were: an energy density of 8 J/cm², a wavelength of 980 nm, a spot size of 0.19 cm², and a power of 50 mW in pulsed contact mode. Irradiation was applied to eight points behind the ear once daily for ten sessions.⁷ The points of irradiation were as follows: five points placed on the surgical incision behind the ear, two points superior/inferior to the incision site, and one point inside the ear. However, the exposure time for each point was 60 seconds. During laser irradiation, the patient was given protective glasses and advised to lie on his/her side and

close his/her eyes.

G2 received only drug interventions. For all the patients in the control and PBM groups, the following drugs were prescribed: dexamethasone (Decadron, corticosteroid and cortisol, Shafadaru) at a dose of 8 mg /twice in the first 24 hours after the operation and cephalexin 500 mg capsules (Cephalexin monohydrate, methyl and beta-2-amino-2-phenylacetamido, Shafadaru) taken every six hours for 5 days. In addition, one acetaminophen 500 mg tablet was prescribed every six hours for 5 days.

The Visual analogue scale (VAS) (0–10 points) and the headache subscale of the neck disability index (NDI) questionnaire were provided to both groups to assess the pain intensity.^{16,17} NDI is a self-reported scale used to assess neck pain and headache.¹⁸ Pain intensity was assessed in both groups before treatment, after sessions 1 and 5, and at the 1- and 3-month follow-ups. The blinded examiner assessed the pain intensity at all times.

Descriptive statistics, including mean, standard deviation (SD), median, and interquartile range (IQR) of all variables, were computed for both groups. The normality assumption was evaluated by the Shapiro-Wilk test, and it was not met for any of the variables. The between-group comparison was made through the Mann-Whitney U test, and the within-group comparison was performed using the Friedman test with pairwise comparisons. All analyses were performed using SPSS statistical software (version 23.0, SPSS Inc, Chicago, IL). *P*-values of less than 0.05 were considered statistically significant.

Results

Table 1 indicates the mean and SD values of demographic and main variables in the PBM and control groups. There were no statistically significant differences in terms of age ($P=0.763$), body mass index ($P=0.342$), and time elapsed from surgery ($P=0.174$) between the two groups.

Descriptive statistics of VAS scores in the two groups at baseline and 4 time-points of the study are shown in **Table 2**. The VAS score was not significantly different between the two groups at baseline. In the PBM group, the pain intensity dramatically decreased from baseline to the end of the study ($P<0.001$). The lowest value was recorded at month 3. A slight significant decrease was also observed in the control group from the baseline until session 5, but the trend was reversed thereafter. The between-group comparison showed significantly lower pain scores in the PBM group compared to the control group at all four time points of the study, resulting in a very large effect size at session 5, month 1, and month 3 of the study.

Table 3 shows the descriptive statistics of the NDI headache subscale in the PBM and control groups at baseline and four time points of measurements. Similarly, the NDI score gradually decreased from the baseline to month 3 in the PMB group ($P<0.001$), while the trend was consistent in the control group, and the lowest score was observed at session 5. The between-group comparison

Table 1. Mean and standard deviation (SD) of variables in PBM and control groups before interventions

Variables	PBM group (n = 64)		Control group (n = 64)		P-Value
	Mean	SD	Mean	SD	
Age (year)	38.7	6.97	37.77	6.67	0.763
Body mass index (kg/m ²)	25.98	5.16	24.18	4.16	0.342
Pain (VAS)	7.59	1.19	8	1.29	0.678
Elapsed time from surgery(m)	6.95	3.89	6.67	3.67	0.174

Table 2. Within-group and between group comparison of pain severity according to VAS

Time-points	PBM group (n = 64)		Control group (n = 64)		Between-group comparison (P;BC)	Effect size
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)		
Baseline (T0)	7.59 (1.19)	8.00 (2)	8.00 (0.99)	8.00 (1)	0.051(0.342)	0.37
Session 1 (T1)	7.09 (1.2)	7.00 (2)	7.67 (1.04)	8.00 (1)	0.004(0.327)	0.51
Session 5 (T2)	2.92 (0.89)	3.00 (2)	6.59 (1.14)	7.00 (1)	<0.001(0.021)	3.59
Month 1 (T3)	1.34 (0.96)	1.00 (1)	7.55 (1.09)	8.00 (1)	<0.001(0.009)	6.05
Month 3 (T4)	0.39 (0.79)	0.00 (1)	7.25 (1.19)	7.5 (2)	<0.001(0.015)	6.79
Within-group comparison (P; BC)	<0.001; (0.004) T4<T0**, T4<T1**, T4<T2**, T3<T0**, T3<T1**, T3<T2**, T2<T0**, T2<T1**		<0.001; (0.006) T0>T1*, T0>T2**, T0>T3**, T1>T2**, T2>T3**, T2>T4*			

SD, Standard deviation; IQR, interquartile range; *P<0.05, **P<0.01; BC, Bonferroni Correction

Table 3. Within-group and between group comparison of pain severity according to NDI

Time-points	PBM group		Control group		Between-group comparison (P;BC)	Effect size
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)		
Baseline (T0)	2.95 (0.7)	3.00 (1)	2.81 (0.73)	3.00 (1)	0.294(0.118)	0.19
Session 1 (T1)	2.94 (0.71)	3.00 (1)	2.81 (0.73)	3.00 (1)	0.361(0.541)	0.18
Session 5 (T2)	1.41 (0.95)	1.00 (1)	2.38 (0.93)	3.00 (1)	<0.001(0.004)	1.03
Month 1 (T3)	0.66 (0.84)	0.00 (1)	2.83 (0.74)	3.00 (1)	<0.001(0.009)	2.74
Month 3 (T4)	0.25 (0.56)	0.00 (0)	2.84 (0.80)	3.00 (1)	<0.001(0.005)	3.75
Within-group comparison (P;BC)	<0.001;(0.009) T4<T0**, T4<T1**, T4<T2**, T3<T2*, T3<T1**, T3<T0**, T2<T1*, T2<T0**		<0.001;(0.004) T0>T2**, T1>T2**, T3>T2**, T4>T2**			

SD, Standard deviation; IQR, interquartile range; *P<0.05, **P<0.01; BC, Bonferroni Correction

revealed that the PBM group had significantly lower values of the NDI score at session 5, month 1, and month 3 ($P<0.001$). The effect size was large at session 5 and very large thereafter.

Discussion

As far as we know, this is the first study applying PBM and drug therapy to the temporal bone in patients after tympanomastoidectomy. The findings of the present study illustrated that the combined effects of PBM and drugs may cause pain reduction in short-term and long-term follow-ups in patients who have undergone tympanomastoidectomy. Nevertheless, PBM did not show immediate effects on pain.

The immediate pain relief of PBM has been shown in some studies.^{6,14,19-21} On the other hand, some studies did not indicate the immediate effects of PBM.^{22,23} It seems that PBM may induce direct photobioinhibitory actions on peripheral nerves, which decrease acute pain.⁶ Li et al. (2019) revealed that multi-focal laser therapy has beneficial immediate effects on pain and functional parameters in patients with knee osteoarthritis.²⁰ Nevertheless, the exact

mechanism of immediate pain reduction is not clear in their study, and they did not consider a control group for further statistical comparisons.²⁰ In the present study, the site of incision, mastoid bone excision, and possible infection after tympanomastoidectomy may delay the immediate effects of PBM.⁷

The present study revealed that the combined effects of PBM and drugs may reduce post-surgical pain in the short term. Some studies confirmed these findings.²⁴ Kaydok et al. showed that low-level laser therapy decreases pain intensity in patients with lateral epicondylitis after short-term and long-term evaluations.²⁴ PBM may stimulate the release of neurotransmitters such as serotonin, enhance mitochondrial adenosine triphosphate (ATP) production, and accelerate the proliferation phase of inflammation.²⁴ The short-term analgesic and anti-inflammatory effects of PBM may prevent fibrosis and other complications after surgery.⁷ Common side effects of pain killers, such as drowsiness, dizziness, fatigue, nystagmus, nausea and memory loss, increase the need for alternative treatments.⁶ Other types of pain management, such as nerve blocks, surgical treatment, and laser therapy, are suggested when

drug treatment is ineffective.⁶ Laser therapy is usually used in the treatment of various diseases such as trigeminal neuralgia and musculoskeletal disorders.¹¹ Several studies have presented the effect of laser therapy on cell function. Mitochondria are the first structures to show the primary effects of absorbing photons. An increase in the activity of cytochrome c oxidase, chromophores, and electron transfer leads to an increase in ATP production.^{6,19-21}

It seems that the rate of pain reduction may influence the rate of recovery after surgery.²¹ In the present study, PBM showed a greater pain reduction rate after 5 sessions of treatment (mean difference: 4.67 cm).

PBM and drug therapy together showed a long-term pain reduction in patients after surgery. A recent review emphasized that adding laser therapy to conventional treatments for neuromuscular disorders can provide more pain relief. Also, the mechanisms of PBM for long-term pain relief are through photobiomodulation, which causes a series of tissue response activation. PBM increases ATP production, vasodilation, and construction of new blood vessels, and it reduces inflammatory response and interleukin.^{16,25} Other mechanisms of pain reduction included; increases the level of beta-endorphin and nitric oxide, reduces the level of bradykinin, cell ion channels regulation, increases action potential of nerve, releases acetylcholine and regenerate nerves.^{26,27} Among the other effects of photobiomodulation, we can mention the increase in DNA, RNA, and collagen production.²⁷ The results of the long-term effects of PBM are conflicting.^{28,29} Langella et al. (2018) investigated the effect of PBM on pain and inflammation after total hip replacement surgery. VAS and blood cytokines enzyme showed a significant reduction compared to the control group.²⁹ On the other hand, Da Silva et al. (2021) concluded that laser therapy combined with exercise or drug did not provide additional benefits for pain relief in patients with chronic pain. Different points and locations of laser therapy should be considered as a confounding factor for the negative results.²⁸

There were some limitations to our study. We applied only the 50 mW laser (mentioned parameters in the method section) to the incision site. Other characteristics of PBM, such as different energy densities, power, or time, should be considered in future studies.

Conclusion

The findings of the present study illustrated that the combined effects of PBM and drugs may cause significant short-term and long-term changes in pain after tympanomastoidectomy. PBM was not effective in reducing pain intensity immediately.

Acknowledgements

The authors would like to thank all participants as well as the Deputy of Research and technology of Guilan University of Medical Sciences for their cooperation.

Authors' Contribution

Conceptualization: Shadman Nemati, Kamran Ezzati

Data curation: Shadman Nemati, Kamran Ezzati, Maryam Shakiba, Hedieh Ramezani

Formal analysis: Maryam Shakiba, Kamran Ezzati, Shadi Salamroudi

Funding acquisition: Shadman Nemati

Investigation: Shadman Nemati, Kamran Ezzati, Ali Faghih Habibi

Methodology: Shadman Nemati, Maryam Shakiba, Hedieh Ramezani

Project administration: Kamran Ezzati, Ali Faghih Habibi, Shadi Salamroudi

Resources: Shadman Nemati

Software: Maryam Shakiba, Hedieh Ramezani

Supervision: Shadman Nemati, Kamran Ezzati

Validation: Maryam Shakiba, Ali Faghih Habibi

Visualization: Kamran Ezzati, Shadi Salamroudi, Hedieh Ramezani

Writing—original draft: Kamran Ezzati, Shadman Nemati, Maryam Shakiba

Writing—review & editing: Ali Faghih Habibi, Shadi Salamroudi, Hedieh Ramezani, Kamran Ezzati, Shadman Nemati

Competing Interests

The authors have no competing interests to declare that are relevant to the content of this article.

Ethical Approval

The study was approved by the ethics committee of Guilan University of Medical Sciences (IR.GUMS.REC.1397.159). All stages of this research have been performed according to the Helsinki Declaration.

Funding

This work was supported by the Deputy of Research and technology of Guilan University of Medical Sciences.

References

1. Glare P, Aubrey KR, Myles PS. Transition from acute to chronic pain after surgery. *Lancet* 2019;393(10180):1537-46. doi:10.1016/s0140-6736(19)30352-6
2. Shipton E. Post-surgical neuropathic pain. *ANZ J Surg* 2008;78(7):548-55. doi:10.1111/j.1445-2197.2008.04569.x
3. Nemati S, Okhovvat SA, Naghavi SE, Shakiba M, Mikaeeli S. Relative frequency of chronic postoperative pain in patients operated for chronic otitis media. *Eur Arch Otorhinolaryngol* 2014;271(8):2139-43. doi:10.1007/s00405-013-2696-5
4. Carmel Neiderman NN, Frisch M, Handzel O, Ungar OJ, Oron Y, Cavel O. Characterization of pain after tympanoplasty and tympanomastoidectomy and analysis of risk factors. A prospective cohort study. *Eur Arch Otorhinolaryngol* 2022;279(4):1765-75. doi:10.1007/s00405-021-06845-y
5. Sommer M, de Rijke JM, van Kleef M, Kessels AG, Peters ML, Geurts JW, et al. The prevalence of postoperative pain in a sample of 1490 surgical inpatients. *Eur J Anaesthesiol* 2008;25(4):267-74. doi:10.1017/s0265021507003031
6. White PF, Elvir Lazo OL, Galeas L, Cao X. Use of electroanalgesia and laser therapies as alternatives to opioids for acute and chronic pain management. *F1000Res* 2017;6:2161. doi:10.12688/f1000research.12324.1
7. Ezzati K, Fekrazad R, Raoufi Z. The Effects of photobiomodulation therapy on post-surgical pain. *J Lasers Med Sci* 2019;10(2):79-85. doi:10.15171/jlms.2019.13
8. Wilkie MD, Tahery J. Laser-assisted tympanomastoidectomy for active mucosal chronic otitis media. *B-ENT* 2016;12(2):125-30.
9. Fyrmpas G, Tsetsos N, Katotomichelakis M, Rudic M. Lasers in endoscopic middle ear surgery: where do we stand today? *Eur Arch Otorhinolaryngol* 2021;278(11):4169-77. doi:10.1007/s00405-021-06807-4
10. Le HT, Huynh NC, Nguyen-Ho QA, Nguyen TT, Le SH, Nguyen LT. Effect of photobiomodulation therapy on reducing acute pain and inflammation following surgical removal

- of impacted mandibular third molars: a randomized, split-mouth clinical trial. *Photobiomodul Photomed Laser Surg* 2022;40(4):245-51. doi:10.1089/photob.2021.0110
11. 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
 12. Hosseinpour S, Tunér J, Fekrazad R. Photobiomodulation in oral surgery: a review. *Photobiomodul Photomed Laser Surg* 2019;37(12):814-25. doi:10.1089/photob.2019.4712
 13. Košec A, Matišić V, Gregurić T, Falak H, Ajduk J, Ries M. Correlation of pre-operative computed tomography, intra-operative findings and surgical outcomes in revision tympanomastoidectomy. *J Laryngol Otol* 2020;134(12):1096-102. doi:10.1017/s0022215120002698
 14. Chow RT, Johnson MI, Lopes-Martins RA, Bjordal JM. Efficacy of low-level laser therapy in the management of neck pain: a systematic review and meta-analysis of randomised placebo or active-treatment controlled trials. *Lancet* 2009;374(9705):1897-908. doi:10.1016/s0140-6736(09)61522-1
 15. Tang Y, Gao M, Zhang T, Zhang M, Tu X, Wang H, et al. A retrospective study of audiological outcomes after endoscopic tympanoplasty and tympanomastoidectomy in patients with cholesteatoma. *Asian J Surg* 2023;46(9):3496-504. doi:10.1016/j.asjsur.2022.09.142
 16. Bielewicz J, Daniluk B, Kamieniak P. VAS and NRS, same or different? Are visual analog scale values and numerical rating scale equally viable tools for assessing patients after microdiscectomy? *Pain Res Manag* 2022;2022:5337483. doi:10.1155/2022/5337483
 17. Mousavi SJ, Parnianpour M, Montazeri A, Mehdian H, Karimi A, Abedi M, et al. Translation and validation study of the Iranian versions of the Neck Disability Index and the Neck Pain and Disability Scale. *Spine (Phila Pa 1976)* 2007;32(26):E825-31. doi:10.1097/BRS.0b013e31815ce6dd
 18. Liang Z, Thomas L, Jull G, Treleaven J. The neck disability index reflects allodynia and headache disability but not cervical musculoskeletal dysfunction in migraine. *Phys Ther* 2022;102(5):pzac027. doi:10.1093/ptj/pzac027
 19. Takenori A, Ikuhiro M, Shogo U, Hiroe K, Junji S, Yasutaka T, et al. Immediate pain relief effect of low-level laser therapy for sports injuries: randomized, double-blind placebo clinical trial. *J Sci Med Sport* 2016;19(12):980-3. doi:10.1016/j.jsams.2016.03.006
 20. Li CF, Chen YJ, Lin TY, Hsiao YH, Fu JC, Chen CH, et al. Immediate responses of multi-focal low-level laser therapy on quadriceps in knee osteoarthritis patients. *Kaohsiung J Med Sci* 2019;35(11):702-7. doi:10.1002/kjm2.12113
 21. de Barros DD, Dos Santos Barros Catão JS, Ferreira ACD, Simões TMS, de Albuquerque Cavalcanti Almeida R, de Vasconcelos Catão MHC. Low-level laser therapy is effective in controlling postoperative pain in lower third molar extractions: a systematic review and meta-analysis. *Lasers Med Sci* 2022;37(5):2363-77. doi:10.1007/s10103-021-03470-3
 22. Yang W, Lin F, Li M, Wei R, Zhou J, Zhou X. Immediate effect in the retina and choroid after 650 nm low-level red light therapy in children. *Ophthalmic Res* 2023;66(1):312-8. doi:10.1159/000527787
 23. Huang Z, Chen J, Ma J, Shen B, Pei F, Kraus VB. Effectiveness of low-level laser therapy in patients with knee osteoarthritis: a systematic review and meta-analysis. *Osteoarthritis Cartilage* 2015;23(9):1437-44. doi:10.1016/j.joca.2015.04.005
 24. Kaydok E, Ordahan B, Solum S, Karahan AY. Short-term efficacy comparison of high-intensity and low-intensity laser therapy in the treatment of lateral epicondylitis: a randomized double-blind clinical study. *Arch Rheumatol* 2020;35(1):60-7. doi:10.5606/ArchRheumatol.2020.7347
 25. Tam SY, Tam VC, Ramkumar S, Khaw ML, Law HK, Lee SW. Review on the cellular mechanisms of low-level laser therapy use in oncology. *Front Oncol* 2020;10:1255. doi:10.3389/fonc.2020.01255
 26. Lyu K, Liu X, Jiang L, Chen Y, Lu J, Zhu B, et al. The functions and mechanisms of low-level laser therapy in tendon repair (review). *Front Physiol* 2022;13:808374. doi:10.3389/fphys.2022.808374
 27. Dompe C, Moncrieff L, Matys J, Grzech-Leśniak K, Kocherova I, Bryja A, et al. Photobiomodulation-underlying mechanism and clinical applications. *J Clin Med* 2020;9(6):1724. doi:10.3390/jcm9061724
 28. da Silva NP, Moretti MP, de Oliveira IP, Aranha AL, Beloni PV, Maciel MF, et al. Laser therapy in the treatment of chronic multi-site pain: a systematic review. *Acta Fisiátrica* 2021;28(3):173-83.
 29. Langella LG, Casalechi HL, Tomazoni SS, Johnson DS, Albertini R, Pallotta RC, et al. Photobiomodulation therapy (PBMT) on acute pain and inflammation in patients who underwent total hip arthroplasty-a randomized, triple-blind, placebo-controlled clinical trial. *Lasers Med Sci* 2018;33(9):1933-40. doi:10.1007/s10103-018-2558-x