"Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic"
by Fisher SR, Rigby JH, Mettler JA, McCurdy KW
Journal of Sport Rehabilitation

Section: Critically Appraised Topic

Article Title: Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic

Authors: Stephen R. Fisher, Justin H. Rigby, Joni A. Mettler, and Kevin W. McCurdy

Affiliations: Texas State University, San Marcos, TX.

Running Head: PBMT vs Cryotherapy for Muscle Recovery

Journal: *Journal of Sport Rehabilitation*

Acceptance Date: May 20, 2018

DOI: https://doi.org/10.1123/jsr.2017-0359

“Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic”
by Fisher SR, Rigby JH, Mettler JA, McCurdy KW
Journal of Sport Rehabilitation

Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic.

Stephan R. Fisher, ATC, LAT (corresponding author)
Texas State University
601 University Dr.
San Marcos, Texas 78666
stephanfisher@txstate.edu
Phone: (512) 245-7586
Fax: (512) 245-3044

Justin H. Rigby, PhD, ATC, LAT
Texas State University
San Marcos, TX

Joni A. Mettler, PhD, ATC, CSCS
Texas State University
San Marcos, TX

Kevin W. McCurdy, PhD, ATC, LAT
Texas State University
San Marcos, TX

"Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic"
by Fisher SR, Rigby JH, Mettler JA, McCurdy KW
Journal of Sport Rehabilitation

Abstract

Clinical Scenario: Cryotherapy is one of the most commonly used modalities for post-exercise muscle recovery despite inconsistencies in the literature validating its effectiveness. With the need to find a more effective modality, photobiomodulation therapy (PBMT) has gained popularity because of recent research demonstrating its ability to accelerate the muscle recovery process. ***Focused Clinical Question:*** Is PBMT more effective than cryotherapy at reducing recovery time and decreasing delayed onset muscle soreness (DOMS) after strenuous exercise? ***Summary of Key Findings:*** Three moderate- to high quality double-blinded, randomized placebo-controlled trials and two low- to moderate quality translational studies performed on rats were included in this CAT. All 5 studies supported the use of PBMT over cryotherapy as a treatment for post-exercise muscle recovery following exercise. PBMT was superior in reducing creatine kinase, inflammation markers, and blood lactate compared to cryotherapy following strenuous/high intensity aerobic or strength muscular exercise. PBMT was also shown to improve post-exercise muscle performance and function more than cryotherapy. ***Clinical Bottom Line:*** There is moderate evidence to suggest the use of PBMT over cryotherapy post-exercise to enhance muscle recovery in trained and untrained athletes. Shorter recovery times and increased muscle performance can be seen 24 to 96 hours following PBMT application. ***Strength of Recommendation:*** Based on consistent findings from all 5 studies, there is grade B evidence to support the use of PBMT over cryotherapy for more effective post-exercise recovery of skeletal muscle performance.

CLINICAL SCENARIO:

Photobiomodulation therapy (PBMT) is a promising modality that has gained popularity in different areas of medical practice. Previously referred to as low-level laser therapy (LLLT) or light emitting diode therapy (LEDT), PBMT has effectively improved muscle performance by increased exercise times, and reduced muscle fatigue limiting post-exercise strength losses.[1] After intense exercise, PBMT confines the degree of exercise induced muscle damage, limiting the need for a large inflammatory process.[2] It also reduces patient-reported muscle soreness, modulates growth factors and myogenic regulatory factors, and increases the formation of new red blood cells locally.[2] These effects make PBMT a valuable treatment option for muscle recovery; however, PBMT has not become a mainstream tool for muscle recovery in clinical practice. For decades, cryotherapy has been a popular modality for post-exercise muscle recovery utilized by many athletes, coaches, and sports medicine practitioners, despite recent challenges to its effectiveness.[3] For these reasons, PBMT should be explored as a substitute to cryotherapy for post-exercise muscle recovery.

FOCUSED CLINICAL QUESTION:

Is PBMT more effective than cryotherapy at reducing muscle recovery time and decreasing delayed onset muscle soreness (DOMS) after strenuous exercise?

SUMMARY OF SEARCH, 'BEST EVIDENCE' APPRAISED, AND KEY FINDINGS:

- The literature was searched for studies of level 2 evidence or higher (based on Oxford Centre of Evidence-Based Medicine 2011, Levels of Evidence) that compared PBMT vs. cryotherapy as a treatment for muscle recovery.

- Three moderate- to high quality double-blinded, randomized placebo-controlled trial studies[4,5] and two low- to moderate quality translational rat studies[6-8] were included in the critical appraisal.
- All five studies[4-8] supported the use of PBMT rather than cryotherapy as treatment for muscle performance recovery following exercise.

CLINICAL BOTTOM LINE:

There is moderate evidence to support the use of PBMT over cryotherapy when using this modality post-exercise for muscle recovery in trained and untrained athletes. Shorter recovery times, identified by a fast return to baseline muscle torque and subjective muscle soreness values, can be seen 24 to 96 hours following PBMT application. Lower markers of muscle damage, creatine kinase (CK), which lead to less inflammation markers, were found 24 to 96 h after PBMT treatments; however, CK levels after cryotherapy treatments followed similar patterns to placebo treatments.

STRENGTH OF RECOMMENDATION:

Based on the Oxford Centre for Evidence-Based Medicine strength of recommendation there is grade B evidence to support the use of PBMT over cryotherapy for post-exercise muscle recovery. The results were consistent across all five studies included in this appraisal.

SEARCH STRATEGY:

Terms used to guide Search Strategy:

- **P**atient/Population/Problem
  - Muscle recovery following strenuous exercise
- **I**ntervention

- Photobiomodulation
- **C**omparison
  - Cryotherapy
- **O**utcome
  - Improve recovery time, decrease muscle soreness

Search Terms Used

Searches included the key terms "photobiomodulation," "low-level laser therapy," "light-emitting diode therapy," "phototherapy," "cryotherapy," "cold-water immersion therapy," "muscle recovery," and "muscle damage."

Sources of Evidence Searched

- MEDLINE
- SPORTDiscus
- Additional articles obtained through hand search of reference lists

INCLUSION AND EXCLUSION CRITERIA

Inclusion

- Articles that investigated a direct comparison between PBMT and cryotherapy for muscle recovery after strenuous exercise
- Articles with treatment post-exercise
- Limited to articles in English
- Level 2 or higher level of evidence

Exclusion

- Articles published before 2007

RESULTS OF SEARCH

Five relevant studies met the inclusion criteria and are categorized in Table 1.

BEST EVIDENCE

The studies listed in Table 1 represent the best available evidence and were included in this critically appraised topic (CAT). The selection of studies was based on the following criteria: included a level of evidence rating of 2 or better, investigated a direct comparison between cryotherapy and PBMT application in relation to muscle recovery following strenuous exercise, and compared the effectiveness of the treatments post-exercise in terms of muscle performance recovery.[4-8]

IMPLICATIONS FOR PRACTICE, EDUCATION, AND FUTURE RESEARCH

All 5 studies reviewed in this CAT support the use of PBMT over cryotherapy when treating trained and non-trained individuals post aerobic and strength exercise for muscle recovery.[4-8] There were no studies found in the literature search that supported cryotherapy over PBMT. Photobiomodulation therapy was more effective in preventing increases in CK levels,[4-8] blood lactate,[5] C-reactive protein,[5,7] and inflammation[6,7] after an exercise bout. In addition, PBMT was able to increase time to exhaustion[7] and better maintain muscular strength following strenuous exercise[4,8] compared to cryotherapy.

Training and competition in athletics can be stressful on an athlete's muscles requiring appropriate treatment to accelerate post-exercise recovery. A quick recovery can maintain muscular function when repeated performance is necessary. After completing an intense exercise, especially one that is unfamiliar, an athlete experiences physiological stress within the affected muscles. Muscle stress causes energy substrate depletion, such as glycogen and ATP, mechanical muscle damage, oxidative stress, inflammation, and neuromuscular fatigue.[9-11] Symptoms such as soreness and decreased muscle function are reported by athletes following strenuous exercise and results in muscle fatigue.[12] Fatigue alters muscle proprioception and activation, which can limit muscular performance in subsequent sport competition or practice.[13]

Many athletes, coaches, and sports medicine professionals utilize cryotherapy as the primary modality for muscle recovery, especially following an intense training session. There continues to be widespread use of cryotherapy techniques post-exercise despite inconsistencies in the literature validating its effectiveness. Cryotherapy decreases the tissue metabolic rate,[14] promotes superficial vasoconstriction,[15] decreases vascular permeability[16] and leads to less edema formation.[12,17] A form of cryotherapy, cold water immersion therapy has an additional effect, due to hydrostatic pressure, at encouraging reabsorption of interstitial fluids found in the muscle after exercise.[18] Cryotherapy is able to improve subjective measures of recovery after intense exercise bouts such as self-reported muscle soreness; however, objective measures of muscle force, lactate, CK, and inflammatory markers are hindered.[3,19,20]

The physiological response resulting from photobiomodulation therapy on muscle recovery is quite different than cryotherapy. Photobiomodulation therapy affects the tissue at the cellular level by inducing a photochemical reaction within the cell. Red and infrared light is absorbed by 1 of 4 membrane-bound complexes within the mitochondria known as cytochrome c oxidase (Cox).[21] Also known as complex IV, Cox is a key chromophore in the respiratory electron transport chain that leads to the production of ATP in the mitochondria. An improvement of mitochondrial function and increase in ATP synthesis within the mitochondria is seen following PBMT application.[22,23] Photobiomodulation therapy has also been shown to reduce circulating reactive oxygen species (ROS) by stimulating an increase in antioxidants and nitric oxide release.[24]

Muscle fibers are damaged as a result from exercise, especially from prolonged or strenuous exercise.[25,26] As a response to this exercised induced muscle damage of the muscle, an inflammatory process occurs to heal and regenerate damage fibers.[12,25] Muscle damage was noted in the included studies following the exercise protocols. This was demonstrated by an increase of CK, blood lactate, and frequency of necrosis, measured by histological analysis, in placebo treatments,[4,5,8] an ice bag application,[4,8] and cold water immersion therapy.[5,7] Compared to placebo treated groups, cryotherapy demonstrated no difference in CK[4,5,8] or blood lactate[5] levels at any time points. Photobiomodulation therapy protected the muscle against damage, in the included studies, with significantly lower levels of muscle damage markers;[4-8] thus, inflammation markers of c-reactive protein[5-7] and leukocyte analysis[6,7] were also lower in groups treated with PBMT.

The ability to maintain muscle strength and function performance between bouts of exercise should be a factor when choosing a modality to promote post-exercise muscle recovery. Oxidative stress increases after intense exercise, decreasing contractile function.[27] Photobiomodulation therapy during repeated high intensity muscular exercise bouts aided in preventing a decrease in maximum voluntary contraction (MVC); however, cryotherapy treatment resulted in significant decreases in MVC.[4,8]

Future research is necessary to optimize treatments that clinicians and athletes use for muscle recovery. Although two of the studies utilized in this CAT were translational rat studies, the results offer valuable information that provides a foundation for future clinical research in human muscle. Additional unbiased *in vivo* human studies are needed to address the physiology behind cryotherapy and photobiomodulation and their respective effects on muscle recovery post-strenuous exercise. Also, continual investigation into the proper treatment parameters for PBMT and cryotherapy is needed, as the various parameters used between studies may impact the study outcomes.

Photobiomodulation therapy research has shown positive results regarding the ability to aid in the recovery and improvement of muscular strength and function. Future research should continue to address optimal parameters, timing and dosage for PBMT, especially comparing high and low powered devices and parameters. All studies we included used low powered PBMT devices. Future photobiomodulation therapy research should also be compared to cryotherapy and other treatment modalities for its effects immediately after musculoskeletal injury. This CAT should be reviewed in 2 years to determine whether additional best-research evidence has been published that could aid in answering the focused clinical question.

References

1. Ferraresi C, Hamblin MR, Parizotto NA. Low-level laser (light) therapy (LLLT) on muscle tissue: performance, fatigue and repair benefited by the power of light. *Photonics & lasers in medicine.* 2012;1(4):267-286.
2. Alves AN, Fernandes KPS, Deana AM, Bussadori SK, Mesquita-Ferrari RA. Effects of low-level laser therapy on skeletal muscle repair: a systematic review. *American Journal Of Physical Medicine & Rehabilitation.* 2014;93(12):1073-1085.
3. Hohenauer E, Taeymans J, Baeyens J-P, Clarys P, Clijsen R. The Effect of Post-Exercise Cryotherapy on Recovery Characteristics: A Systematic Review and Meta-Analysis. *Plos One.* 2015;10(9):e0139028-e0139028.
4. de Paiva PR, Tomazoni SS, Johnson DS, et al. Photobiomodulation therapy (PBMT) and/or cryotherapy in skeletal muscle restitution, what is better? A randomized, double-blinded, placebo-controlled clinical trial. *Lasers Med Sci.* 2016;31(9):1925-1933.
5. Leal Junior EC, de Godoi V, Mancalossi JL, et al. Comparison between cold water immersion therapy (CWIT) and light emitting diode therapy (LEDT) in short-term skeletal muscle recovery after high-intensity exercise in athletes--preliminary results. *Lasers Med Sci.* 2011;26(4):493-501.
6. Camargo MZ, Siqueira CPCM, Preti MCP, et al. Effects of light emitting diode (LED) therapy and cold water immersion therapy on exercise-induced muscle damage in rats. *Lasers in Medical Science.* 2012;27(5):1051-1058.
7. da Costa Santos VB, de Paula Ramos S, Milanez VF, et al. LED therapy or cryotherapy between exercise intervals in Wistar rats: anti-inflammatory and ergogenic effects. *Lasers Med Sci.* 2014;29(2):599-605.
8. De Marchi T, Schmitt VM, Machado GP, et al. Does photobiomodulation therapy is better than cryotherapy in muscle recovery after a high-intensity exercise? A randomized, double-blind, placebo-controlled clinical trial. *Lasers in Medical Science.* 2017;32(2):429-437.
9. Leeder J, Gissane C, van Someren K, Gregson W, Howatson G. Cold water immersion and recovery from strenuous exercise: a meta-analysis. *British Journal of Sports Medicine.* 2012;46(4):233-240.
10. Barnett A. Using Recovery Modalities between Training Sessions in Elite Athletes: Does it Help? *Sports Medicine.* 2006;36(9):781-796.
11. Finsterer J. Biomarkers of peripheral muscle fatigue during exercise. *BMC MUSCULOSKELETAL DISORDERS.* 2012;13.
12. Cheung K, Hume PA, Maxwell L. Delayed Onset Muscle Soreness: Treatment Strategies and Performance Factors. *Sports Medicine.* 2003;33(2):145-164.
13. Ballantyne BT, Shields RK. Quadriceps fatigue alters human muscle performance during a novel weight bearing task. *Medicine & Science in Sports & Exercise.* 2010;42(9):1712-1722.

14. Merrick MA. Secondary injury after musculoskeletal trauma: a review and update. *Journal of athletic training.* 2002;37(2):209-217.

15. Selkow N, Herman D, Liu Z, Hertel J, Hart J, Saliba S. Blood Flow After Exercise-Induced Muscle Damage. *Journal of athletic training.* 2015;50(4):400-406.

16. Meeusen R, Lievens P. The Use of Cryotherapy in Sports Injuries. *Sports Medicine.* 1986;3(6):398-414.

17. Bleakley CM, Davison GW. What is the biochemical and physiological rationale for using cold-water immersion in sports recovery? A systematic review. *British Journal of Sports Medicine.* 2010;44(3):179-187.

18. Wilcock I, Cronin J, Hing W. Physiological Response to Water Immersion: A Method for Sport Recovery? *Sports Medicine.* 2006;36(9):747-765.

19. Crystal NJ, Townson DH, Cook SB, Laroche DP. Effect of cryotherapy on muscle recovery and inflammation following a bout of damaging exercise. *Eur J Appl Physiol.* 2013;113(10):2577-2586.

20. Pointon M, Duffield R, Cannon J, Marino FE. Cold application for neuromuscular recovery following intense lower-body exercise. *Eur J Appl Physiol.* 2011;111(12):2977-2986.

21. Albuquerque-Pontes GM, Vieira RdP, Tomazoni SS, et al. Effect of pre-irradiation with different doses, wavelengths, and application intervals of low-level laser therapy on cytochrome c oxidase activity in intact skeletal muscle of rats. *Lasers In Medical Science.* 2015;30(1):59-66.

22. Silveira PCL, Silva LAd, Fraga DB, Freitas TP, Streck EL, Pinho R. Evaluation of mitochondrial respiratory chain activity in muscle healing by low-level laser therapy. *Journal of Photochemistry and Photobiology B: Biology.* 2009;95(2):89-92.

23. Xu X, Zhao X, Liu TC-Y, Pan H. Low-Intensity Laser Irradiation Improves the Mitochondrial Dysfunction of C2C12 Induced by Electrical Stimulation. *Photomedicine and Laser Surgery.* 2008;26(3):197-202.

24. Avni D, Levkovitz S, Maltz L, Oron U. Protection of Skeletal Muscles from Ischemic Injury: Low-Level Laser Therapy Increases Antioxidant Activity. *Photomedicine and Laser Surgery.* 2005;23(3):273-277.

25. Armstrong RB, Warren GL, Warren JA. Mechanisms of Exercise-Induced Muscle Fibre Injury. *Sports Medicine.* 1991;12(3):184-207.

26. Appell H-J, Soares JMC, Duarte JAR. Exercise, Muscle Damage and Fatigue. *Sports Medicine.* 1992;13(2):108-115.

27. Reid MB, Haack KE, Franchek KM, Valberg PA, Kobzik L, West MS. Reactive oxygen in skeletal muscle. I. Intracellular oxidant kinetics and fatigue in vitro. *Journal of Applied Physiology.* 1992;73(5):1797-1804.

"Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic"
by Fisher SR, Rigby JH, Mettler JA, McCurdy KW
Journal of Sport Rehabilitation

Table 1: Summary of Study Designs of Articles Retrieved.

Level of Evidence	Study Design	Number located	References
1	Double-blinded, Randomized, Placebo-Controlled Clinical Trial	3	de Pavia et al.[4] Leal Junior et al.[5] de Marchi et al.[8]
2	Translational Rat Studies	2	Camargo et al.[6] de Costa Santos et al.[7]

"Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic" by Fisher SR, Rigby JH, Mettler JA, McCurdy KW
Journal of Sport Rehabilitation

Table 2: Characteristics of Included Studies.

Article	**de Costa Santos et al.**[7]	**Camargo et al.**[6]	**de Marchi et al.**[8]	**de Pavia et al.**[4]	**Leal Junior et al.**[5]
Study Design	Translational Study	Translational Study	Randomized, Double-blinded, Placebo-controlled Trial	Randomized, Double-blinded, Placebo-controlled Trial	Cross-over, Randomized, Double-blinded, Placebo-Controlled Trial
Participants	29 male Wistar rats randomized into 4 groups: control (Co, n=6), exercised + passive recovery (PR, n=6), exercised + cryotherapy (Cryo, n=8), and exercised + LED therapy (LED, n=9)	32 male Wistar rats randomized into 4 groups (n=8): control (Co), exercised (E), exercised + CWI (CWI), and exercised + LED phototherapy (LED).	40 male volunteers aged between 19 and 29 years old. Randomized to 5 groups: Placebo (PG), Photobiomodulation therapy (PBMT), Cryotherapy (CG), Cryotherapy-PBMT (CPG), PBMT-Cryotherapy (PCG)	50 untrained male participants aged between 18 and 25, randomized to 5 groups (n=10): Placebo, PBMT, Cryotherapy, Cryotherapy+PBMT, PBMT+Cryotherapy	6 male professional futsal players from Brazil randomized to receive either CWIT, active LEDT, or placebo LEDT in a random manner after 3 exercise tests.
Intervention Investigated	PD 300 Standard Photodiode Sensor (Ophir Optronics, Jerusalem, Israel). *Parameters for LEDT:* 940 nm wavelength and a spectral bandwidth of 45 nm in 4 min intervals, 4 J/cm^2 of energy intensity, 9.5 mW/cm^2 power density, 160 mW power output, 1	PD 300 Standard Photodiode Sensor (Ophir Optronics, Jerusalem, Israel). *Paramaters for LEDT:* 940-nm wavelength with a spectral bandwidth of 45 nm in intervals of 7 min and 15s to administer 4 J/cm^2 of energy intensity, 9.5 mW/cm^2 power density, 160 mW power output, 1 cm^2 irradiation area on each hind leg.	PBMT: 69 LED (34 red 660nm, 35 infrared 850nm) cluster probe (THOR® Photomedicine London, UK), continuous frequency, output power=10mW red, 30mW infrared, LED spot size=0.2 cm^2, total spot size=13.8 cm^2, power density=0.05 W cm^{-2} (red), 0.15 W cm^{-2} (infrared), energy=41.7J, 30s treatment time, 1 irradiation point per muscle.	PBMT: Cordless, portable GameDay™ device (Multi Radiance Medical, Solon, OH, USA). One super pulsed infrared 905nm laser, dose=0.375J; 4 red LEDS, dose=4.5J; 4 infrared LEDs, dose=5.25J; total dose per site=39.37J; irradiation time per site=300s; applied to 6 sites of quadriceps femoris.	LEDT: Cluster probe with 34 LED diodes of 660 nm (red) and 35 LED diodes of 850 nm (infrared) (THOR® Photomedicine, London, United Kingdom), continuous frequency, optical output=10mW (red) and 30mW (infrared), spot size=0.2 cm^2, power density=0.05 W/cm^2 (red) and 0.15 W/cm^2 (infrared), energy=41.7 J each

Article	de Costa Santos et al.[7]	Camargo et al.[6]	de Marchi et al.[8]	de Pavia et al.[4]	Leal Junior et al.[5]
	cm^2 irradiation area on each hind leg. *Parameters for Cryotherapy:* hind legs immersed in 10°C for 10 min. *Exercise Protocol:* Animals were submitted to 45 min of swimming exercise followed by 25 min of recovery and then a second bout of either 45 min or time to exhaustion.	*Parameters for Cryotherapy:* hind legs were immersed in 10°C for 10 min. *Exercise Protocol:* The exercise groups (E, CWI, LED) swam for 100 min in a plastic container	Cryotherapy: muscle belly of biceps. Ice bag applicaton of 20 min. *Muscle fatigue protocol*: On Biodex Systems 4 Pro isokinetic dynamometer, five sets of 10 eccentric/concentric contractions of the elbow flexors separated by 30s. Performed with an amplitude of 90° and speed of 90° $.seg^{-1}$ for eccentric and 180° $.seg^{-1}$ for concentric.	*Eccentric exercise protocol*: On Biodex Systems 4 Pro isokinetic dynamometer, 75 eccentric isokinetic contractions in non-dominant leg (5 sets of 15, 30s rest between sets) at a velocity of 60° $.seg^{-1}$ in both flexion and extension of knee with a 60° range of motion	point, 10 irradiation points, 30s each point, 5 min total. CWIT: Standing position with lower limbs immersed to the gonadal region 5 °C for 5 min. *Fatigue test protocol*: at the 1st, 2nd, and 3rd session of study, subjects performed a Wingate test on a cycle ergometer. It consisted of cycling at maximum speed for 30s against a load of 7.5% of their respective body weight
Outcome Measures	CK and CRP levels from blood samples, histology analysis (necrosis %, edema %, inflammation % and cell count), swimming performance (min)	Blood samples collected immediately after exercise for blood lactate measurement. Blood samples collected at 24 h for creatine kinase and hematological analysis. Histological analysis of soleus muscles to determine damaged	Maximal voluntary contractions were measured using the isokinetic dynamometer (Biodex System 4 Pro, Biodex Medical Systems, USA), DOMS soreness measured through the 100-mm visual analog scale (VAS), Blood samples were collected at	Blood samples were taken at 1min, 1h, 24h, 48h, 72h, and 96h after eccentric protocol to evaluate CK activity. A visual analog scale (VAS) of 100-mm was used to assess DOMS intensity. Maximal voluntary contractions were assessed utilizing the	Blood samples were collected 3min and 20min after exercise for blood lactate, CK, and CRP analysis. Peak Power and Mean Power were assessed with the Wingate Cycle Test.

Article	de Costa Santos et al.[7]	Camargo et al.[6]	de Marchi et al.[8]	de Pavia et al.[4]	Leal Junior et al.[5]
		muscle fibers, inflammatory cell infiltrate, and edema.	5min, 60min, 24h, 48h, and 72h to measure oxidative damage to protiens (carbonylated proteins nanomole of DNPH/gram/deciliter of proteins), CK levels, and oxidative damage to lipids (TBARS nmol/ml)	isokinetic dynamometer (System 4, Biodex®, USA).	
Main Findings	24 hours after exercise there was an increase of total leukocytes in PR and Cryo groups. CK levels were only increased significantly in the Cryo group. CRP was more pronounced in the PR group. PR group had increased areas with cell necrosis compared to control, the LED group had significantly less than the PR group.	LED group showed fewer areas of muscle damage and inflammatory cell infiltration than E and CWI groups. LED group also presented with lower levels of CK activity than the E group. CWI and LED did not reduce edema areas. No significant effect on leukocyte counts in either treatment group.	Significant increases in MVC capacity and decrease in DOMS in PBMT, CPG, and PCG groups compared to PG and CG groups ($p<0.05$), no significant differences between CG and PG. Significant decrease in TBARS concentration in PBMT, CPG, PCG groups compared to PG ($p<0.01$), CG had significant decreases at 1h ($p<0.01$), 48h ($p<0.05$), and 72h ($p<0.01$). Significant decrease in PC concentrations in PBMT, CG, and PCG compared to	PBMT significantly increased MVC compared to placebo from 24h to 96h ($p<0.05$). PBMT+cryotherapy had similar outcomes to PBMT alone. However, cryotherapy+PBMT and cryotherapy alone were not different from placebo. Significant differences occurred between PBMT and placebo for DOMS at 1h to 96h after exercise; PBMT+cryotherapy was only significant between 1h to 48h compared to placebo ($p<0.05$).	No significant differences in peak power or mean power among groups in the Wingate cycle test. CK activity increased after each test but there were no differences between test sessions. Active LEDT decreased CK levels significantly compared to post-exercise values ($p=0.0065$). Placebo and CWIT did not significantly decrease CK levels. Active LEDT significantly decreased

Article	de Costa Santos et al.[7]	Camargo et al.[6]	de Marchi et al.[8]	de Pavia et al.[4]	Leal Junior et al.[5]
	PR and Cryo groups presented more areas of edema than control, the LED group did not show any signs of edema. The Control group had the lowest frequency of fields of inflammatory cells followed by LED, PR, and Cryo groups, respectfully, with significant differences between each group. The Cryo group showed the highest density of inflammatory cells per field. There were no significant differences in CK levels between groups after 24 hours. Performance was significantly better in LED and Cryo groups than PR. The LED		PG ($p<0.01$); CPG had significant decreases in 24-72h ($p<0.01$). Significant decrease in CK levels in PBMT compared to PG ($p<0.01$); the PCG and CPG presented significant decreases in 48h($p<0.05$) and 72h ($p<0.01$).	The PBMT group did not have significant increases in CK levels compared to placebo from 24h to 96h. PBMT+cryotherapy was not as effective but still significantly better than placebo. Cryotherapy as a single treatment and crotherapy+PBMT were no different from placebo.	blood lactate levels from post-exercise ($p=0.0044$), placebo and CWIT were not significant. CRP levels did not significantly decrease after any treatment however, a tendency to decrease from baseline values was found for active LEDT.

Article	**de Costa Santos et al.[7]**	**Camargo et al.[6]**	**de Marchi et al.[8]**	**de Pavia et al.[4]**	**Leal Junior et al.[5]**
	group had the best performance.				
Level of Evidence	2b	2b	1b	1b	1b
Validity Score (PEDRO)	N/A (Animal Study)	N/A (Animal Study)	7	9	8
Conclusion	LED PBMT is more efficient at preventing muscle damage and inflammatory reactions than passive recovery or cryotherapy. LED and cryotherapy also improved exercise performance.	LED PBMT is more efficient than CWI in preventing muscle damage and local inflammatory reactions after exercise. This may be due to its anti-inflammatory effects and preservation of muscle fiber cell membrane integrity.	Isolated PBMT treatment is the best option to improve muscle recovery in both short term and long term. Isolated cryotherapy was unable to provide muscle recovery. Combined PBMT and cryotherapy treatments do not improve recovery effects.	PBMT as a single treatment was the best for post-exercise recovery and provided the greatest reduction in DOMS.	5 min of LEDT was more effective than placebo to reduce levels of biochemical markers related to muscle recovery. CWIT was not significantly different from the placebo.

"Photobiomodulation Therapy is More Effective than Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic" by Fisher SR, Rigby JH, Mettler JA, McCurdy KW
Journal of Sport Rehabilitation

Table 3: Photobiomodulation Therapy Parameters

Article	**da Costa Santos et al[7]**	**Camargo et al.[6]**	**de Marchi et al.[8]**	**de Pavia et al.[4]**	**Leal Junior et al.[5]**
Wavelength	940 nm (infrared)	940 nm (infrared)	660 nm (red), 850 nm (infrared)	905 nm (super-pulsed infrared laser), 640 nm (red diodes), 875 nm (infrared diodes)	660 nm (red), 850 nm (infrared)
Power Output	160 mW	160 mW	10 mW (red), 30 mW (infrared)	1.25 mW (super-pulsed infrared laser), 15 mW (red diodes), 17.5 mW (infrared diodes)	10 mW (red), 30 mW (infrared)
Power Density	9.5 mW/cm^2	9.5 W/cm^2	0.05 W/cm^2, 0.15 W/cm^2	2.84 mW/cm^2 (super-pulsed infrared laser), 16.67 mW/cm^2 (red diodes), 19.44 mW/cm^2 (infrared diodes)	0.05 W/cm^2 (red), 0.15 W/cm^2 (infrared)
Treatment Time	240s	435s	30s	300s	300s
Irradiation Area Size	1 cm^2	1 cm^2	13.8 cm^2 (red and infrared)	7.64 cm^2 (super-pulsed infrared laser, red and infrared diodes)	138 cm^2 (red and infrared)
Number of Diodes	Not specified	Not specified	69 (34 red LEDs and 35 infrared LEDs)	1 super-pulsed infrared laser, 4 red LEDs, 4 infrared LEDs	69 (34 red diodes and 35 infrared diodes)
Energy	4 J	4 J	41.7 J	39.37 J	417 J total (208.50 J each lower limb)
Energy Density	4 J/cm^2	4 J/cm^2	1.5 J/cm^2 (red), 4.5 J/cm^2 (infrared)	0.85 J/cm^2 (super-pulsed infrared laser), 5 J/cm^2 (red diodes), 5.83 J/cm^2 (infrared diodes)	1.5 J/cm^2 (red), 4.5 J/cm^2 (infrared)