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Human Kinetics
CRITICALLY APPRAISED TOPIC

The Effectiveness of Photobiomodulation Therapy Versus Cryotherapy for Skeletal Muscle Recovery: A Critically Appraised Topic

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Clinical Scenario: Cryotherapy is one of the most commonly used modalities for postexercise 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 after strenuous exercise? ***Summary of Key Findings:*** Three moderate- to high-quality double-blinded, randomized, placebo-controlled trials and 2 low- to moderate-quality translational studies performed on rats were included in this critically appraised topic. All 5 studies supported the use of PBMT over cryotherapy as a treatment for postexercise muscle recovery following exercise. PBMT was superior in reducing creatine kinase, inflammation markers, and blood lactate compared with cryotherapy, following strenuous/high intensity aerobic or strength muscular exercise. PBMT was also shown to improve postexercise muscle performance and function more than cryotherapy. ***Clinical Bottom Line:*** There is moderate evidence to suggest the use of PBMT over cryotherapy postexercise 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 postexercise recovery of skeletal muscle performance.

Keywords: laser therapy, light therapy, cold therapy, cold-water immersion therapy, post-exercise

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 or light-emitting diode therapy, PBMT has effectively improved muscle performance by increasing exercise times and reducing muscle fatigue limiting postexercise 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 postexercise 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 postexercise muscle recovery.

Focused Clinical Question

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

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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 versus cryotherapy as a treatment for muscle recovery.
- Three moderate- to high-quality double-blinded, randomized, placebo-controlled trial studies[4,5] and 2 low- to moderate-quality translational rat studies[6–8] were included in the critical appraisal.
- All 5 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 postexercise 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 hours 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 postexercise muscle recovery. The results were consistent across all 5 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 keyterms "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 postexercise
- 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 2 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 postexercise 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 nontrained individuals postaerobic and strength exercise for muscle recovery.[4–8] There were no studies found in the literature search that supported cryotherapy over PBMT. The PBMT 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 with cryotherapy.

Training and competition in athletics can be stressful on an athlete's muscles requiring appropriate treatment to accelerate postexercise 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 adenosine triphosphate (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 postexercise 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

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 Paiva et al[4] Leal Junior et al[5] De Marchi et al[8]
2	Translational rat studies	2	Camargo et al[6] da Costa Santos et al[7]

Table 2 Characteristics of Included Studies

Article	da Costa Santos et al[7]	Camargo et al[6]	De Marchi et al[8]	de Paiva 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 + 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. Randomized into 5 groups: PG, PBMT, CG, CPG, and PCG.	50 untrained male participants aged between 18 and 25, randomized into 5 groups (n = 10): PG, PBMT, cryotherapy, cryotherapy + PBMT, PBMT + cryotherapy.	6 male professional futsal players from Brazil randomized to receive either CWIT, active LEDT, or PG 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-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.	PD 300 standard photodiode sensor (Ophir Optronics). *Parameters for LEDT:* 940-nm wavelength with a spectral bandwidth of 45 nm in intervals of 7 min and 15 s to administer 4-J/cm^2 of energy intensity, 9.5-m W/cm^2 power density, 160-mW power output, 1-cm^2 irradiation area on each hind leg. *Parameters for cryotherapy:* hind legs were immersed in 10°C for 10 min. *Exercise protocol:* The exercise groups (E, CWI, and LED) swam for 100 min in a plastic container.	PBMT: 69 LED (34 red 660 nm and 35 infrared 850 nm) cluster probe (THOR® Photomedicine, London, United Kingdom), continuous frequency, output power = 10-mW red, 30-mW 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 = 41.7 J, 30-s treatment time, 1 irradiation point per muscle. Cryotherapy: muscle belly of biceps. Ice bag application of 20 min. *Muscle fatigue protocol*: On Biodex Systems 4 Pro isokinetic dynamometer, 5 sets of 10 eccentric/concentric contractions of the elbow flexors separated by 30 s. Performed with an amplitude of 90° and speed of 90° per seg for eccentric and 180° per seg for concentric.	PBMT: cordless, portable GameDay™ device (Multi Radiance Medical, Solon, OH). One super-pulsed infrared 905-nm laser, dose = 0.375 J; 4 red LEDS, dose = 4.5 J; 4 infrared LEDs, dose = 5.25 J; total dose per site = 39.37 J; irradiation time per site = 300 s; applied to 6 sites of quadriceps femoris. *Eccentric exercise protocol*: On Biodex Systems 4 Pro isokinetic dynamometer, 75 eccentric isokinetic contractions in nondominant leg (5 sets of 15, 30-s rest between sets) at a velocity of 60° per seg in both flexion and extension of knee with a 60° range of motion	LEDT: cluster probe with 34 LED diodes of 660 nm (red) and 35 LED diodes of 850 nm (infrared) (THOR®), continuous frequency, optical output = 10 mW (red) and 30 mW (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 point, 10 irradiation points, 30 s 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 first, second, and third sessions of study, subjects performed a Wingate test on a cycle ergometer. It consisted of cycling at maximum speed for 30 s 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), and swimming performance (in minutes)	Blood samples collected immediately after exercise for blood lactate measurement. Blood samples collected at 24 h for CK and hematological analysis. Histological analysis of soleus muscles to determine damaged muscle fibers, inflammatory cell infiltrate, and edema.	Maximal voluntary contractions were measured using the isokinetic dynamometer (Biodex System 4 Pro; Biodex Medical Systems Inc, Shirley, NY), DOMS soreness measured through the 100-mm VAS, Blood samples were collected at 5 min, 60 min, 24 h, 48 h, and 72 h to measure oxidative damage to proteins (carbonylated proteins nanomole of 2,4-dinitrophenylhydrazine/gram/deciliter of proteins), CK levels, and oxidative damage to lipids (thiobarbituric acid reactive substances nmol/mL).	Blood samples were taken at 1 min, 1 h, 24 h, 48 h, 72 h, and 96 h after eccentric protocol to evaluate CK activity. A VAS of 100 mm was used to assess DOMS intensity. Maximal voluntary contractions were assessed utilizing the isokinetic dynamometer (System 4, Biodex®).	Blood samples were collected 3 and 20 min after exercise for blood lactate, CK, and CRP analysis. Peak power and mean power were assessed with the Wingate Cycle Test.

(continued)

Table 2 (continued)

Article	da Costa Santos et al[7]	Camargo et al[6]	De Marchi et al[8]	de Paiva et al[4]	Leal Junior et al[5]
Main findings	24 h 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 with control, the LED group had significantly less than the PR group. 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 h. Performance was significantly better in LED and Cryo groups than PR. The LED group had the best performance.	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 with PG and CG ($P < .05$), no significant differences between CG and PG. Significant decrease in thiobarbituric acid reactive substances concentration in PBMT, CPG, and PCG groups compared with PG ($P < .01$), CG had significant decreases at 1 h ($P < .01$), 48 h ($P < .05$), and 72 h ($P < .01$). Significant decrease in PC concentrations in PBMT, CG, and PCG compared with PG ($P < .01$); CPG had significant decreases in 24–72 h ($P < .01$). Significant decrease in CK levels in PBMT compared with PG ($P < .01$); the PCG and CPG presented significant decreases in 48 h ($P < .05$) and 72 h ($P < .01$).	PBMT significantly increased MVC compared with PG from 24 to 96 h ($P < .05$). PBMT + cryotherapy had similar outcomes to PBMT alone. However, cryotherapy + PBMT and cryotherapy alone were not different from PG. Significant differences occurred between PBMT and PG for DOMS at 1–96 h after exercise; PBMT + cryotherapy was only significant between 1 and 48 h compared with PG ($P < .05$). The PBMT group did not have significant increases in CK levels compared with PG from 24 to 96 h. PBMT + cryotherapy was not as effective but still significantly better than PG. Cryotherapy as a single treatment and cryotherapy + PBMT were not different from PG.	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 with postexercise values ($P = .01$). PG and CWIT did not significantly decrease CK levels. Active LEDT significantly decreased blood lactate levels from postexercise ($P = .004$), PG 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.
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 PR 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 postexercise recovery and provided the greatest reduction in DOMS.	5 min of LEDT was more effective than PG to reduce levels of biochemical markers related to muscle recovery. CWIT was not significantly different from the PG.

Abbreviations: CG, cryotherapy group; CK, creatine kinase; CPG, cryotherapy-photobiomodulation therapy group; CRP, C-reactive protein; CWI, cold-water immersion; CWIT, cold water immersion therapy; DOMS, delayed onset muscle soreness; LEDT, light-emitting diode therapy; MVC, maximum voluntary contraction; PBMT, photobiomodulation therapy; PCG, photobiomodulation therapy-cryotherapy group; PG, placebo group; PR, passive recovery; seg, segment; VAS, visual analog scale.

Table 3 Photobiomodulation Therapy Parameters

Article	da Costa Santos et al[7]	Camargo et al[6]	De Marchi et al[8]	de Paiva et al[4]	Leal Junior et al[5]
Wavelength, nm	940 (infrared)	940 (infrared)	660 (red) and 850 (infrared)	905 (super-pulsed infrared laser), 640 (red diodes), and 875 (infrared diodes)	660 (red) and 850 (infrared)
Power output, mW	160	160	10 (red) and 30 (infrared)	1.25 (super-pulsed infrared laser), 15 (red diodes), and 17.5 (infrared diodes)	10 (red) and 30 (infrared)
Power density	9.5 mW/cm^2	9.5 mW/cm^2	0.05 W/cm^2 (red) and 0.15 W/cm^2 (infrared)	2.84 mW/cm^2 (super-pulsed infrared laser), 16.67 mW/cm^2 (red diodes), and 19.44 mW/cm^2 (infrared diodes)	0.05 W/cm^2 (red) and 0.15 W/cm^2 (infrared)
Treatment time, s	240	435	30	300	300
Irradiation area size, cm^2	1	1	13.8 (red and infrared)	7.64 (super-pulsed infrared laser, red diodes, and infrared diodes)	138 (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, and 4 infrared LEDs	69 (34 red diodes and 35 infrared diodes)
Energy, J	4	4	41.7	39.37	417 J total (208.50 J each lower limb)
Energy density, J/cm^2	4	4	1.5 (red) and 4.5 (infrared)	0.85 (super-pulsed infrared laser), 5 (red diodes), and 5.83 (infrared diodes)	1.5 (red) and 4.5 (infrared)

Abbreviation: LEDs, light-emitting diodes.

muscle force, lactate, CK, and inflammatory markers are hindered.[3,19,20]

The physiological response resulting from PBMT on muscle recovery is quite different than cryotherapy. PBMT affects the tissue at the cellular level by inducing a photochemical reaction within the cell. Red and infrared light is absorbed by one 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] PBMT has also been shown to reduce circulating reactive oxygen species 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 exercise-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 with placebo treated groups, cryotherapy demonstrated no difference in CK[4,5,8] or blood lactate[5] levels at any time points. PBMT 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 postexercise muscle recovery. Oxidative stress increases after intense exercise, decreasing contractile function.[27] PBMT during repeated high-intensity muscular exercise bouts aided in preventing a decrease in maximum voluntary contraction; however, cryotherapy treatment resulted in significant decreases in maximum voluntary contraction.[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 poststrenuous 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. PBMT parameters for the included studies are listed in Table 3.

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 PBMT research should also be compared with cryotherapy and other treatment modalities for its effects immediately after musculoskeletal injury. This CAT should be reviewed in 2 years to determine whether the additional best-research evidence has been published that could aid in answering the focused clinical question.

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