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MASTERCLASS

Clinical and scientific recommendations for the use of photobiomodulation therapy (PBMT) in exercise performance enhancement and post-exercise recovery: current evidence and future directions

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KEYWORDS
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Abstract
Background: There is about ten years since the first randomized controlled trial (RCT) looking for the effects of photobiomodulation therapy (PBMT) using low-level laser therapy (LLLT) and/or light emitting diodes therapy (LEDT) in athletic performance enhancement was published. Since then, the knowledge in this field has increasing exponentially.
Objective: Given the fast advance in clinical interest, research and development in the use of PBMT for athletic performance enhancement and also to accelerate post-exercise recovery, as pioneers in this research field we felt the need to establish recommendations to ensure the correct use of the therapy, and also to guide the further studies in this area looking for the achievement of highest scientific evidence. It is important to highlight that the establishment of both clinical and scientific recommendations in this masterclass article were based on the most recent systematic reviews with meta-analysis and RCTs published in this field.

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Background

Ten years ago, in 2008, the first randomized controlled trial (RCT) investigating the use of photobiomodulation therapy (PBMT) for athletic performance enhancement was published[1] only two years after the first animal study in this field be published.[2] This pioneer RCT[1] showed for the very first time that the treatment with PBMT before an exercise session could enhance the performance of high-level volleyball athletes, decrease the delayed onset muscle fatigue, and prevent the expected increase of blood lactate levels.

In the next two years a series of RCTs involving elite athletes was published by our group investigating different PBMT parameters as well as different functional and biochemical markers.[3–8] The outcomes of these RCTs confirmed the potential of PBMT as an ergogenic agent, and a therapeutic tool to enhance post-exercise recovery. After the initial skepticism started to decrease, then other research groups started to develop and publish studies in the same area.[9–12] Their results mostly confirmed what was previously observed, and the knowledge in this field started to increase exponentially.

At the year of 2013, the first meta-analysis in this field was published by our research group[13] (ahead of print version), and at that time 13 RCTs with acceptable methodological quality were included and the outcomes showed that PBMT was able to increase the number of repetitions and the time to exhaustion if applied before an exercise session. Four years later the most recent meta-analysis was published[14] now including 39 RCTs, and for the very first time it was possible to clearly identify a therapeutic dose window for large and small muscle groups. This increasing evidence lead to the International Olympics Committee to recommend PBMT as a therapeutic agent to improve acute muscular recovery,[15] which is an unquestionable milestone to this field.

Currently, only one year after the publication of the most recent meta-analysis,[14] we can identify more than 50 RCTs published in this field showing that PBMT can not only increase exercise performance in healthy subjects in a laboratory-controlled environment, but also in high-level athletes in field tests[16] and in real sports settings,[17] in patients with different medical conditions such as chronic obstructive pulmonary disease (COPD),[18,19] fibromyalgia,[20] and chronic kidney disease.[21] This fast growing has also attracted the industry's interest, leading to the development of devices designed specifically for exercise performance enhancement.

Given the fast advance in clinical interest, research and development in the use of PBMT for athletic performance enhancement and also to accelerate post-exercise recovery, we felt the need to establish a guideline to ensure the correct use of the therapy, and also to guide the further studies in this area looking for the achievement of highest scientific evidence. It is important to highlight that the establishment of both clinical and scientific guidelines below were based on the most recent systematic review and meta-analysis published in this field,[14,22] and we considered also the RCTs published after the publication of this systematic review, up to October 2018.

Clinical recommendations

PBMT, also known as phototherapy, is a nonthermal process where light interacts with chromophores leading to photophysical and photochemical reactions in different tissues. PBMT is a light therapy that uses non-ionizing light sources, such as lasers, light emitting diodes (LEDs), and broadband light, from the visible to the infrared spectrum.

As mentioned before, the following parameters described in this guideline were extracted from the most recent systematic reviews with meta-analysis in this field,[14,22] and also from the RCTs with high methodological quality published after the aforementioned reviews, up to October 2018.

- *Light source*: Lasers and/or LEDs;
- *Dose*: 20 to 60 J dose for small muscle groups (i.e. biceps brachii or triceps surae), 60 to 300 J for large muscle groups (i.e. quadriceps and hamstrings);
- *Power*: 50 to 200 mW per diode (for single probes); 10 to 35 mW per diode (for cluster probes). The total power of the device can not lead to thermal effects;
- *Wavelengths*: 640 nm (red) to 950 nm. More recently, most studies published in this field have combined red and infrared wavelengths simultaneously;
- *Mode*: Pulsed or continuous;
- *When to irradiate*: For acute effects (a single event) 5 min to 6 h before activity.[16,17,23] For chronic effects associated to strength training the irradiation must be performed immediately before each exercise session (5 to 10 min).[24] For chronic effects associated to endurance training (treadmill) the irradiation must be performed immediately before and immediately after each exercise session (5 to 10 min)[25];
- *Length of irradiation*: minimum of 30 s per site/point;
- *Where to irradiate*: The irradiation must cover as much of the area as possible in most (preferably all) muscle groups involved in exercise activity. If single probes are being used, the distance between irradiation sites/points must be lower than 2 cm;
- *Irradiation technique*: Direct contact with skin (stationary) with slight pressure.

A special highlight must be given regarding the current dose range established in the most recent systematic review.[14] It was evidenced that 75% of doses that presented positive results for performance enhancement in large muscle groups were between 60 J and 300 J, and that 85% of doses that presented positive results for performance enhancement in small muscle groups were between 20 J and 60 J (Fig. 1).

However, as mentioned previously, since the publication of the most recent systematic review[14] we can identify the publication of more 16 RCTs, up to October 2018.[25–40] Taking into consideration the doses that presented positive outcomes in these RCTs,[25–37,39,40] we were able to identify that currently around 70% of doses that presented positive results for performance enhancement in large muscle groups are between 120 J and 300 J, and that around 77% of doses that presented positive results for performance enhancement in small muscle groups stay between 20 J and 60 J (Fig. 2).

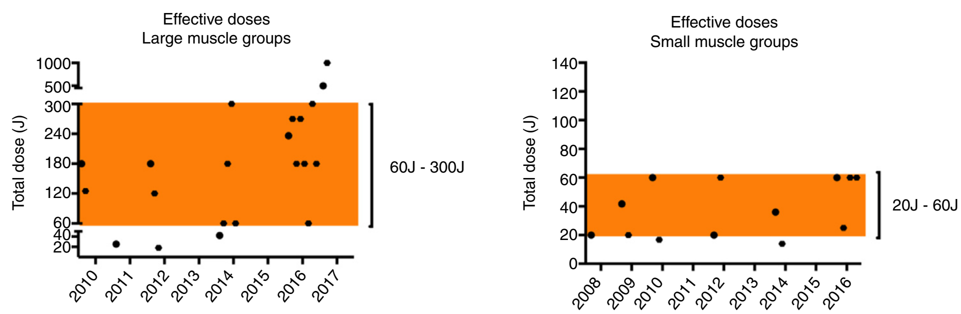

Figure 1 Current therapeutic window based on most recent systematic review[14] in the research field.

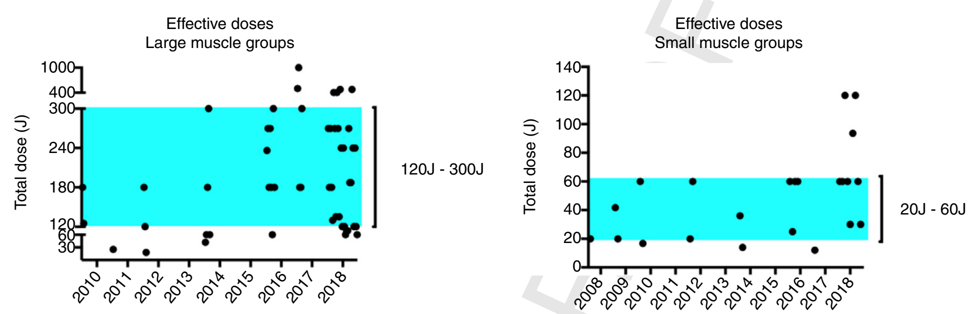

Figure 2 Updated therapeutic window considering the 16 RCTs[25–40] published after the systematic review,[14] up to October 2018.

Interestingly, among all of the sixteen recent published studies above mentioned[25–40] that used doses inside the proposed 120 J to 300 J dose therapeutic window for large muscle groups, there is only one[38] that did not get positive outcomes for performance enhancement. Moreover, in the same study[38] a high dose of 180 J was used for calf muscles, which is 3 times higher than the 60 J dose threshold recommended for small muscle groups.

It is important to highlight also that in studies comparing doses inside the 120 J to 300 J therapeutic window against doses above 300 J for large muscle groups (405 J and 480 J for instance), the doses inside the 120 J to 300 J therapeutic window presented better outcomes.

Scientific recommendations

Despite the growing body of evidence supporting the use of PBMT for performance enhancement and to accelerate post-exercise recovery, the quality of evidence needs to be improved. The recent systematic reviews with meta-analysis in this field[14,22] showed low to moderate quality of evidence to the main outcomes, demonstrating that further research is needed to be confident about the effects. We attribute this quality level of evidence mainly to the risk of bias category and the imprecision of the results due the small sample size and wide confidence intervals observed in the outcomes.

We strongly recommend the attention of researchers to perform the prospective register of study protocol (and to publish the protocol in peer-reviewed journals when possible),[41,42] to follow the Consolidated Standards of Reporting Trials (CONSORT) guidelines when designing the trials, and the use of the TIDeR checklist (template for intervention description and replication) to confirm if all items required were reported in the manuscript before submission.[43,44] This is a way to reduce reporting bias and assist the authors to follow an adequate, clear, and transparent reporting of data and study design.

A special attention must be paid for the report of crossover trials since there is not a specific guideline for it. Furthermore, future studies should present their data in absolute values and their respective variation, as mean and standard deviation (± SD), with detailed description besides percentages, change in outcomes, etc. Further concern should be taken in reporting PBMT parameters. These parameters should be shown in detailed form, such as in a table in the manuscript, to provide more information for the reader regarding the features of the device used and allow the study replication by other authors. Also, it is important to state if the parameters used match or not to the current scientific evidence in order to advance on it.

Final considerations

It is important to stress that these recommendations were based on most recent systematic reviews with meta-analysis and RCTs published in this research field. Future guidelines must follow the same direction and must be based only at the highest scientific evidence, avoiding overstatements and extrapolations based on animal experiments and case-studies for instance.

Conflicts of interest

Professor Ernesto Cesar Pinto Leal-Junior receives research support from Multi Radiance Medical (Solon, OH), a laser device manufacturer. Multi Radiance Medical had no role in the planning of this masterclass article, and the statements are not based in their devices. The remaining authors declare that they have no conflict of interests.

References

1. Leal Junior EC, Lopes-Martins RA, Dalan F, et al. Effect of 655-nm low-level laser therapy on exercise-induced skeletal muscle fatigue in humans. *Photomed Laser Surg*. 2008;26:419–424.
2. Lopes-Martins RA, Marcos RL, Leonardo PS, et al. Effect of low-level laser (Ga-Al-As 655 nm) on skeletal muscle fatigue induced by electrical stimulation in rats. *J Appl Physiol (1985)*. 2006;101:283–288.
3. Leal Junior EC, Lopes-Martins RA, Vanin AA, et al. Effect of 830 nm low-level laser therapy in exercise-induced skeletal muscle fatigue in humans. *Lasers Med Sci*. 2009;24:425–431.
4. Leal Junior EC, Lopes-Martins RA, Baroni BM, et al. Effect of 830 nm low-level laser therapy applied before high-intensity exercises on skeletal muscle recovery in athletes. *Lasers Med Sci*. 2009;24:857–863.
5. Leal Junior EC, Lopes-Martins RA, Baroni BM, et al. Comparison between single-diode low-level laser therapy (LLLT) and LED multi-diode (cluster) therapy (LEDT) applications before high-intensity exercise. *Photomed Laser Surg*. 2009;27:617–623.
6. Leal Junior EC, Lopes-Martins RA, Rossi RP, et al. Effect of cluster multi-diode light emitting diode therapy (LEDT) on exercise-induced skeletal muscle fatigue and skeletal muscle recovery in humans. *Lasers Surg Med*. 2009;41:572–577.
7. Leal Junior EC, Lopes-Martins RA, Frigo L, et al. Effects of low-level laser therapy (LLLT) in the development of exercise-induced skeletal muscle fatigue and changes in biochemical markers related to postexercise recovery. *J Orthop Sports Phys Ther*. 2010;40:524–532.
8. 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;26:493–501.
9. Baroni BM, Leal Junior EC, De Marchi T, Lopes AL, Salvador M, Vaz MA. Low level laser therapy before eccentric exercise reduces muscle damage markers in humans. *Eur J Appl Physiol*. 2010;110:789–796.
10. Baroni BM, Leal Junior EC, Geremia JM, Diefenthaeler F, Vaz MA. Effect of light-emitting diodes therapy (LEDT) on knee extensor muscle fatigue. *Photomed Laser Surg*. 2010;28:653–658.
11. Vieira WH, Ferraresi C, Perez SE, Baldissera V, Parizotto NA. Effects of low-level laser therapy (808 nm) on isokinetic muscle performance of young women submitted to endurance training: a randomized controlled clinical trial. *Lasers Med Sci*. 2012;27:497–504.
12. Toma RL, Tucci HT, Antunes HK, et al. Effect of 808 nm low-level laser therapy in exercise-induced skeletal muscle fatigue in elderly women. *Lasers Med Sci*. 2013;28:1375–1382.
13. Leal-Junior EC, Vanin AA, Miranda EF, de Carvalho Pde T, Dal Corso S, Bjordal JM. Effect of phototherapy (low-level laser therapy and light-emitting diode therapy) on exercise performance and markers of exercise recovery: a systematic review with meta-analysis. *Lasers Med Sci*. 2015;30:925–939.
14. Vanin AA, Verhagen E, Barboza SD, Costa LOP, Leal-Junior ECP. Photobiomodulation therapy for the improvement of muscular performance and reduction of muscular fatigue associated with exercise in healthy people: a systematic review and meta-analysis. *Lasers Med Sci*. 2018;33:181–214.
15. Hainline B, Derman W, Vernec A, et al. International Olympic Committee consensus statement on pain management in elite athletes. *Br J Sports Med*. 2017;51:1245–1258.
16. Pinto HD, Vanin AA, Miranda EF, et al. Photobiomodulation therapy improves performance and accelerates recovery of high-level rugby players in field test: a randomized, crossover, double-blind, placebo-controlled clinical study. *J Strength Cond Res*. 2016;30:3329–3338.
17. De Marchi T, Leal-Junior ECP, Lando KC, et al. Photobiomodulation therapy before futsal matches improves the staying time of athletes in the court and accelerates post-exercise recovery. *Lasers Med Sci*. 2018, http://dx.doi.org/10.1007/s10103-018-2643-1 [Epub ahead of print].
18. Miranda EF, Leal-Junior EC, Marchetti PH, Dal Corso S. Acute effects of light emitting diodes therapy (LEDT) in muscle function during isometric exercise in patients with chronic obstructive pulmonary disease: preliminary results of a randomized controlled trial. *Lasers Med Sci*. 2014;29:359–365.
19. Miranda EF, de Oliveira LV, Antonialli FC, Vanin AA, de Carvalho Pde T, Leal-Junior EC. Phototherapy with combination of super-pulsed laser and light-emitting diodes is beneficial in improvement of muscular performance (strength and muscular endurance), dyspnea, and fatigue sensation in patients with chronic obstructive pulmonary disease. *Lasers Med Sci*. 2015;30:437–443.
20. da Silva MM, Albertini R, de Tarso Camillo de Carvalho P, et al. Randomized, blinded, controlled trial on effectiveness of photobiomodulation therapy and exercise training in the fibromyalgia treatment. *Lasers Med Sci*. 2018;33:343–351.
21. Macagnan FE, Baroni BM, Cristofoli ÉZ, Godoy M, Schardong J, Plentz RDM. Acute effect of photobiomodulation therapy on handgrip strength of chronic kidney disease patients during hemodialysis. *Lasers Med Sci*. 2018, http://dx.doi.org/10.1007/s10103-018-2593-7 [Epub ahead of print].
22. Machado AF, Micheletti JK, Lopes JSS, et al. Phototherapy on management of creatine kinase activity in general versus localized exercise: a systematic review and meta-analysis. *Clin J Sport Med*. 2018, http://dx.doi.org/10.1097/JSM.0000000000000606 [Epub ahead of print].
23. Rossato M, Dellagrana RA, Sakugawa RL, Lazzari CD, Baroni BM, Diefenthaeler F. Time response of photobiomodulation therapy on muscular fatigue in humans. *J Strength Cond Res*. 2018, http://dx.doi.org/10.1519/JSC.0000000000002339 [Epub ahead of print].
24. Vanin AA, Miranda EF, Machado CS, et al. What is the best moment to apply phototherapy when associated to a strength training program? A randomized, double-blinded, placebo-controlled trial: Phototherapy in association to strength training. *Lasers Med Sci*. 2016;31:1555–1564.
25. Miranda EF, Tomazoni SS, de Paiva PRV, et al. When is the best moment to apply photobiomodulation therapy (PBMT) when associated to a treadmill endurance-training program? A randomized, triple-blinded, placebo-controlled clinical trial. *Lasers Med Sci*. 2018;33:719–727.
26. De Marchi T, Schmitt VM, Danúbia da Silva Fabro C, et al. Phototherapy for improvement of performance and exercise recovery: comparison of 3 commercially available devices. *J Athl Train*. 2017;52:429–438.
27. Lanferdini FJ, Bini RR, Baroni BM, Klein KD, Carpes FP, Vaz MA. Improvement of performance and reduction of fatigue with low-level laser therapy in competitive cyclists. *Int J Sports Physiol Perform*. 2018;13:14–22.

28. Ferreira Junior A, Kaspchak LAM, Bertuzzi R, Okuno NM. Effects of light-emitting diode irradiation on time to exhaustion at maximal aerobic speed. *Lasers Med Sci*. 2018;33:935–939.
29. de Oliveira AR, Vanin AA, Tomazoni SS, et al. Pre-exercise infrared photobiomodulation therapy (810 nm) in skeletal muscle performance and postexercise recovery in humans: what is the optimal power output? *Photomed Laser Surg*. 2017;35:595–603.
30. Dellagrana RA, Rossato M, Sakugawa RL, Lazzari CD, Baroni BM, Diefenthaeler F. Dose–response effect of photobiomodulation therapy on neuromuscular economy during submaximal running. *Lasers Med Sci*. 2018;33:329–336.
31. Lanferdini FJ, Krüger RL, Baroni BM, et al. Low-level laser therapy improves the VO(2) kinetics in competitive cyclists. *Lasers Med Sci*. 2018;33:453–460.
32. Barbosa R, Marcolino A, Souza V, Bertolino G, Fonseca M, Guirro R. Effect of low-level laser therapy and strength training protocol on hand grip by dynamometry. *J Lasers Med Sci*. 2017;8:112–117.
33. Ferreira Junior A, Schamne JC, de Moraes SMF, Okuno NM. Cardiac autonomic responses and number of repetitions maximum after LED irradiation in the ipsilateral and contralateral lower limb. *Lasers Med Sci*. 2018;33:353–359.
34. Miranda EF, Tomazoni SS, de Paiva PRV, et al. When is the best moment to apply photobiomodulation therapy (PBMT) when associated to a treadmill endurance-training program? A randomized, triple-blinded, placebo-controlled clinical trial. *Lasers Med Sci*. 2018;33:719–727.
35. Rossato M, Dellagrana RA, Sakugawa RL, Lazzari CD, Baroni BM, Diefenthaeler F. Time response of photobiomodulation therapy on muscular fatigue in humans. *J Strength Cond Res*. 2018, http://dx.doi.org/10.1519/JSC.0000000000002339 [Epub ahead of print].
36. Dellagrana RA, Rossato M, Sakugawa RL, Baroni BM, Diefenthaeler F. Photobiomodulation therapy on physiological and performance parameters during running tests: dose–response effects. *J Strength Cond Res*. 2018;32:2807–2815.
37. Toma RL, Oliveira MX, Renno ACM, Laakso EL. Photobiomodulation (PBM) therapy at 904 nm mitigates effects of exercise-induced skeletal muscle fatigue in young women. *Lasers Med Sci*. 2018;33:1197–1205.
38. Beltrame T, Ferraresi C, Parizotto NA, Bagnato VS, Hughson RL. Light-emitting diode therapy (photobiomodulation) effects on oxygen uptake and cardiac output dynamics during moderate exercise transitions: a randomized, crossover, double-blind, and placebo-controlled study. *Lasers Med Sci*. 2018;33:1065–1071.
39. Mezzaroba PV, Pessôa Filho DM, Zagatto AM, Machado FA. LED session prior incremental step test enhance VO(2max) in running. *Lasers Med Sci*. 2018;33:1263–1270.
40. De Marchi T, Leal-Junior ECP, Lando KC, et al. Photobiomodulation therapy before futsal matches improves the staying time of athletes in the court and accelerates post-exercise recovery. *Lasers Med Sci*. 2018, http://dx.doi.org/10.1007/s10103-018-2643-1 [Epub ahead of print].
41. Tomazoni SS, Costa LDCM, Guimarães LS, et al. Effects of photobiomodulation therapy in patients with chronic non-specific low back pain: protocol for a randomised placebo-controlled trial. *BMJ Open*. 2017;7:e017202.
42. Machado AF, Micheletti JK, Vanderlei FM, et al. Effect of low-level laser therapy (LLLT) and light-emitting diodes (LEDT) applied during combined training on performance and post-exercise recovery: protocol for a randomized placebo-controlled trial. *Braz J Phys Ther*. 2017;21:296–304.
43. Hariohm K, Jeyanthi S, Kumar JS, Prakash V. Description of interventions is under-reported in physical therapy clinical trials. *Braz J Phys Ther*. 2017;21:281–286.
44. Nascimento DP, Gonzalez GZ, Araujo AC, Costa LOP. Description of low back pain clinical trials in physical therapy: a cross sectional study. *Braz J Phys Ther*. 2018, http://dx.doi.org/10.1016/j.bjpt.2018.09.002 [Epub ahead of print].

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