Immediate effects of photobiomodulation therapy combined with a static magnetic field on the subsequent performance: a preliminary randomized crossover triple-blinded placebo-controlled trial

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Abstract: There is evidence about the effects of photobiomodulation therapy (PBMT) alone and combined with a static magnetic field (PBMT-sMF) on skeletal muscle fatigue, physical performance and post-exercise recovery in different types of exercise protocols and sports activity. However, the effects of PBMT-sMF to improve the subsequent performance after a first set of exercises are unknown. Therefore, the aim of this study was to investigate the effects of PBMT-sMF, applied between two sets of exercises, on the subsequent physical performance. A randomized, crossover, triple-blinded (assessors, therapist, and volunteers), placebo-controlled trial was carried out. Healthy non-athlete male volunteers were randomized and treated with a single application of PBMT-sMF and placebo between two sets of an exercise protocol performed on isokinetic dynamometer. The order of interventions was randomized. The primary outcome was fatigue index and the secondary outcomes were total work, peak work, and blood lactate levels. Twelve volunteers were randomized and analyzed to each sequence. PBMT-sMF decreased the fatigue index compared to the placebo PBMT-sMF at second set of the exercise protocol (MD = -6.08, 95% CI -10.49 to -1.68). In addition, PBMT-sMF decreased the blood lactate levels post-intervention, and after the second set of the exercise protocol compared to placebo (p<0.05). There was no difference between PBMT-sMF and placebo in the remaining outcomes tested. Volunteers did not report adverse events. Our results suggest that PBMT-sMF is able to decrease skeletal muscle fatigue, accelerating post-exercise recovery and, consequently, increasing subsequent physical performance when applied between two sets of exercises.

1. Introduction

Skeletal muscle fatigue can be defined as a decrease in maximum strength or in power output, i.e., a decrease in the physical performance, in response to a contractile activity [1]. This decrease in performance can occur through peripheral fatigue process and/or by central fatigue process [1,2]. The peripheral component is produced by changes in the neuromuscular junction, while

the central component of fatigue originates in the central nervous system, decreasing the neural impulse to the muscle [1,3]. The skeletal muscle fatigue development will depend on types of muscle fiber involved, the intensity and duration of the activity performed, the exercise modality employed, besides several interacting factors, and inter-individual differences [2]. The skeletal muscle fatigue is a reversible phenomenon and the physical performance is recovered after a period of rest [4].

Currently there are several therapeutic agents used in clinical practice to decrease skeletal muscle fatigue and enhance the post-exercise recovery. Among them, there are new therapies emerging such as pneumatic compression [5] and extracorporeal shock wave [6], despite the scarce evidence about their positive effects. Among the most used methods, massage and cryotherapy can be highlighted. However, the effectiveness of both strategies is still inconclusive and controversial [7–10]. For instance, a recent systematic review with meta-analysis showed that massage can improve delayed onset muscle soreness (DOMS), however it has no advantage in improving fatigue [9]. Another systematic review with meta-analysis concluded that cryotherapy also improves DOMS recovery, but it is not effective to modulate biochemical markers such as blood lactate, creatine kinase and inflammatory cytokines [10]. On the other hand, there is evidence that photobiomodulation therapy (PBMT) alone or combined with static magnetic field (PBMT-sMF) is an effective ergogenic agent [11–13]. Therefore, although the evidence available shows some positive effects in favor of massage and cryotherapy, and solid effects of PBMT and PBMT-sMF in this field, further studies are still necessary to compare the efficacy of these therapeutic agents against each other.

PBMT alone has been used for years in different clinical conditions. However, the first evidence demonstrating the effects of this therapeutic agent in reducing fatigue, improving performance and accelerating post-exercise recovery is relatively recent [14]. Since then, the body of evidence about the use of PBMT as a post-exercise recovery strategy has become robust, including two systematic reviews with meta-analysis [11,12]. In addition, PBMT has been used combined with static magnetic field (sMF) in order to have better effects from the synergy between these two therapeutic agents [15–21], generating a greater transfer of electrons [22]. sMF interacts with biological systems triggering physiological effects [23]. sMF enhances the positive effects of PBMT increasing mitochondrial respiratory chain activity, production of adenosine triphosphate (ATP), and consequently increasing cell metabolism [22]. Therefore, PBMT-sMF as well as PBMT alone, has been shown to be an effective ergogenic agent [15–21]. Furthermore, in clinical settings PBMT-sMF has shown better ergogenic effects that PBMT alone [24].

In the last years, it has been demonstrated the effects of PBMT alone and PBMT-sMF on skeletal muscle fatigue, physical performance and post-exercise recovery in different types of exercise protocols and sports activity [11,12]. However, there is an important question that remains unanswered. To date, it is unknown whether the application of PBMT-sMF is able to decrease fatigue and accelerate post-exercise recovery to the point of improving the subsequent performance after a first set of exercise. There are several sports activities such as soccer, basketball, long jump and high jump competitions, in which the time to rest between competitions or sets of exercises is not enough for the athlete's recovery. Thus, ergogenic agents are valuable strategies in these sports' scene, especially if they have quick action and can be used in the interval of games or competitions. Therefore, we aimed investigate the effects of PBMT-sMF, applied between two sets of exercises, on the subsequent physical performance.

2. Materials and methods

2.1. Design

A retrospectively registered (NCT04934709), randomized, crossover, triple-blinded (patients, therapists and outcome assessors), placebo-controlled trial was carried out at the Laboratory of Phototherapy and Innovative Technologies in Health at Universidade Nove de Julho, São

Paulo, Brazil. The allocation ratio used was a 1:1. The washout period was 7 days between phase 1 and 2. The protocol was repeated on the same day of the week and at the same time, in order to minimize the effects of the circadian cycle and daily life habits of the volunteers on the variables analyzed. There were no deviations to methods from the protocol. This trial adheres to Consolidated Standards of Reporting Trials (CONSORT) guidelines.

2.2. Ethics statements

This trial was submitted and approved by the Research Ethics Committee of Nove de Julho University (Protocol No. 665332). All participants eligible for the trial were informed by trial assessors of the objective and all procedures, and were required to complete the consent form.

2.3. Characterization of sample

Since no previous trials determined the effects of PBMT-sMF applied between two sets of exercises on the subsequent physical performance and employing this same exercise protocol, the number of patients per group was calculated based on the results of a pilot study carried out by our research group to estimate the sample size involving four volunteers and the same crossover design. The calculation was made considering a β value of 20% and α value of 5%. In the pilot study, the administration of PBMT-sMF resulted in a fatigue index at the second set of exercise of 52.32% ($\pm$ 3.24), whereas placebo PBMT-sMF resulted in a fatigue index of 56.03% ($\pm$ 4.12). The SPH Analytics website was used for the calculation of sample size: https://www.sphanalytics.com/sample-size-calculator-using-average-values/.

Using the parameters listed above, a total of 12 volunteers per group/treatment was determined. Since the trial has a crossover design, this represents the total number of volunteers.

2.4. Inclusion criteria

  i. Male healthy volunteers;

 ii. Non-athletes or those who practiced physical activity up to once a week;

iii. Aged 18-35 years.

2.5. Exclusion criteria

  i. History of musculoskeletal injuries in the hip and knee regions in the two months prior to the trial;

 ii. Use of pharmacological agents and nutritional supplements;

iii. Chronic joint disease in the non-dominant lower limb.

2.6. Randomization and blinding

The order of interventions was randomized. Codes were generated through the random.org website to ensure that 50% of volunteers received the active intervention and 50% of volunteers received the placebo intervention at first phase, in order to counterbalance participants between the two interventions tested (active PBMT-sMF and placebo PBMT-sMF) during the two phases. During the second phase, volunteers received the opposite intervention compared to the applied in the first phase. The randomization was performed by a participating researcher who was not involved in any procedure of the trial. This same researcher was responsible for programming the PBMT-sMF device according to the result of the randomization, as active or placebo mode. This researcher was instructed not to disclose the programmed intervention to the assessor, therapist or any of the volunteers and other researchers involved in the trial until its completion. The assessors, therapist, and volunteers were blinded throughout the treatment. Concealed allocation was achieved through the use of sequentially numbered, sealed and opaque envelopes.

2.7. Interventions

The active PBMT-sMF and placebo PBMT-sMF were performed using the same device and the irradiated sites were the same in both therapies (Fig. 1). To ensure blinding for therapists and patients, the device emitted the same sounds and the same information on the display regardless of the programmed mode (active or placebo). Furthermore, because the device produces a non-significant amount of heat [25], the volunteers were not able to know if active or placebo PBMT-sMF were administered.

Fig. 1. Irradiation sites.

Volunteers underwent intervention (active PBMT-sMF and placebo PBMT-sMF) in the non-dominant lower limb according to prior randomization. A single application was performed at each phase of this trial, between the first and second set of the exercise protocol. Specification of interventions is described below:

1. Active PBMT-sMF: PBMT-sMF was applied employing the Multi Radiance Medical Super Pulsed Laser MR4 console (Solon, Ohio, USA) with a LaserShower cluster probe as emitter. Six different sites of the knee extensor muscles (two medial, two lateral and two central points) were irradiated at the same time. The total time of irradiation was 228 s and a total of 180 J was delivered. The PBMT-sMF parameters were tested and previously optimized [26]. In addition, the irradiation sites were selected based on previous studies and in order to cover as much of the area as possible in the muscle groups involved in the exercise protocol [13,26,27]. The full description of PBMT-sMF parameters is provided in Table 1.

2. Placebo PBMT-sMF: Placebo PBMT-sMF was delivered using the same device that active PBMT-sMF but without any emission of therapeutic dose. Placebo PBMT-sMF was applied in the same sites and with the same time of application as the active PBMT-sMF.

Table 1. Parameters of PBMT-sMF[a]

Number of lasers	4 Super-pulsed-infrared
Wavelength (nm)	905 ($\pm$1)
Frequency (Hz)	250
Peak power (W) (each)	12.5
Average mean optical output (mW) (each)	0.3125
Power density (mW/cm^2) (each)	0.71
Energy density (J/cm^2) (each)	0.162
Dose (J) (each)	0.07125
Spot size of the laser (cm^2) (each)	0.44
Number of red LEDs	4
Wavelength of the red-LEDs (nm)	640 ($\pm$10)
Frequency (Hz)	2
Average optical output (mW) (each)	15
Power density (mW/cm^2) (each)	16.66
Energy density (J/cm^2) (each)	3.8
Dose (J) (each)	3.42
Spot size of the red-LED (cm^2) (each)	0.9
Number of infrared-LEDs	4
Wavelength of the infrared-LEDs (nm)	875 ($\pm$10)
Frequency (Hz)	16
Average optical output (mW) (each)	17.5
Power density (mW/cm^2) (each)	19.44
Energy density (J/cm^2) (each)	4.43
Dose (J) (each)	3.99
Spot size of the LED (cm^2) (each)	0.9
Static magnetic field (mT)	35
Irradiation time per site (s)	228
Total dose per site (J)	30
Total dose applied per lower limb (J)	180
Aperture of the device (cm^2)	20
Application mode	Cluster probe held stationary in skin contact at an angle of 90° and slight pressure

[a]LED, light-emitting diode.

2.8. Procedures

The trial was performed in two phases (first and second phases), since it was a crossover trial, with a washout period of 7 days between phases. Each phase consisted of two exercise sets (set 1 and set 2). The procedures in the first and second phases were exactly the same: 1) Blood samples were collected (blood samples pre-exercise); 2) Volunteers performed stretching and warm-up; 3) Immediately after, the volunteers performed the first set of the exercise protocol (set 1); 4) Three minutes after the end of the set 1, the blood samples were collected again (blood samples post-exercise set 1); 5) Two minutes after, volunteers received irradiation of active PBMT-sMF or placebo PBMT-sMF according to the prior randomization; 6)Three minutes after the intervention, blood samples were collected again (blood samples post-intervention); 7) Two minutes after, the

volunteers performed the second set of the exercise protocol (set 2); 8) Three minutes after the end of the set 2, the blood samples were collected again (blood samples post-exercise set 2):

- Blood samples and biochemical analysis: Blood samples were collected from the volunteers' fingertips. After finger asepsis with alcohol, puncture was performed with a disposable lancet. The first blood drop was discarded to avoid contamination with sweat, and then 25 μL of blood were collected. Blood analysis involved the determination of lactate levels through the electroenzymatic method, in accordance to the Accutrend Lactate Plus Roche (Basel, Switzerland) portable-lactate-analyzer's manufacturer guidelines. The analyzer had a coefficient of variation in the range of 1.8% to 3.3% (ICC $r = 0.999$), with a good reliability for intra- and inter-analyzers, and between test strips [28].

- Stretching and warm-up: The volunteers performed 3 sets of 60 s of active stretching of the knee extensor musculature of the non-dominant lower limb. Then, the volunteers performed the warm-up exercise, which consisted of pedaling for 5 min on a cycloergometer (Inbramed, Brazil), at 100 rpm with no load.

- Exercise protocol: The same exercise protocol was performed at first and second sets. The volunteers were placed in the seat of an isokinetic dynamometer (System 4, Biodex, USA) with an angle of 100° between the trunk and hip. The dominant leg was positioned at 100° of hip flexion and was secured to the seat by a belt. The non-dominant leg was attached to the seat of the dynamometer also by a belt. The volunteers were secured to the seat by two belts crossing their torso. The exercise protocol consisted of two consecutive sets of 40 repetitions of concentric knee flexions and extensions with the non-dominant leg, with 30 s rest between the sets, at 120°/s speed and movement amplitude of 90° (between 10° and 100° of knee flexion, 0° corresponds to the total knee extension). Volunteers exerted maximal force during knee extension and sub maximal force during knee flexion. The volunteers were verbally encouraged during the exercise protocol. Despite the diversity of protocols proposed in the literature for the execution of concentric exercises in isokinetic dynamometers, this protocol was chosen due its efficiency and reproducibility in muscle fatigue generated by exercise [29].

2.9. Outcomes

The primary outcome was fatigue index, measured by isokinetic dynamometer during the exercise protocol. The secondary outcomes were total work and peak torque measured by isokinetic dynamometer during the exercise protocol; and blood lactate, measured by blood samples collected before, 3 minutes after the first set of the exercise protocol, 3 minutes after the application of the intervention and 3 minutes after the second set of the exercise protocol. The fatigue index, total work and peak torque were variables provided directly by the isokinetic dynamometer. There were no any changes to trial outcomes after the trial commenced.

2.10. Statistical analysis

The statistical analysis followed intention-to-treat principles (i.e., the participants were analyzed in the groups to which they were allocated) [30]. The findings were tested for normality using the Kolmogorov-Smirnov test and were determined to have a normal distribution. Data were expressed as the mean and standard deviation, and a two-way repeated measures ANOVA was performed to test between-group differences at each timepoint (treatment effects), mean difference (MD) and 95% confidence intervals (CI), followed by the Bonferroni post hoc test. The significance level was set at $p < 0.05$. In the graphs data are expressed as the mean and standard error of the mean (SEM).

3.   Results

3.1.   Recruitment and baseline data

Twelve healthy male volunteers were randomized between May and September 2015. The twelve volunteers finished all procedures of this trial. The mean age of volunteers was 24.07 (±4.32), height was 173.25 cm (±6.99), and body mass was 74.41 kg (±10.49). Patients did not report any adverse events. The CONSORT flowchart that summarizes the experimental procedures and volunteers is shown in Fig. 2.
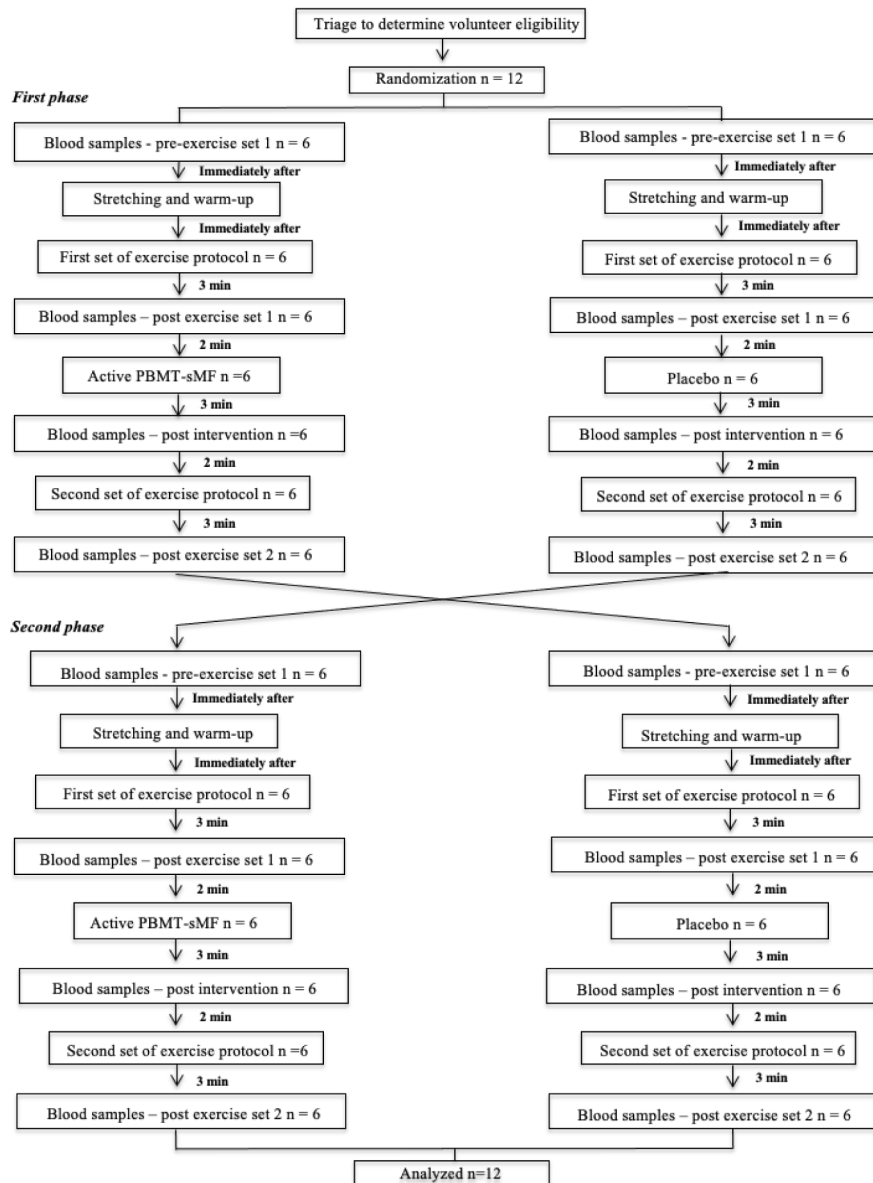

Fig. 2. Enrollment and randomization.

3.2. Primary outcome

There was no difference between interventions at first set of the exercise protocol (MD = 0.60, 95% CI - 3.80 to 5.00). In contrast, at second set of the exercise protocol the PBMT-sMF decreased the fatigue index compared to the placebo PBMT-sMF (MD = - 6.08, 95% CI -10.49 to - 1.68) (Fig. 3).
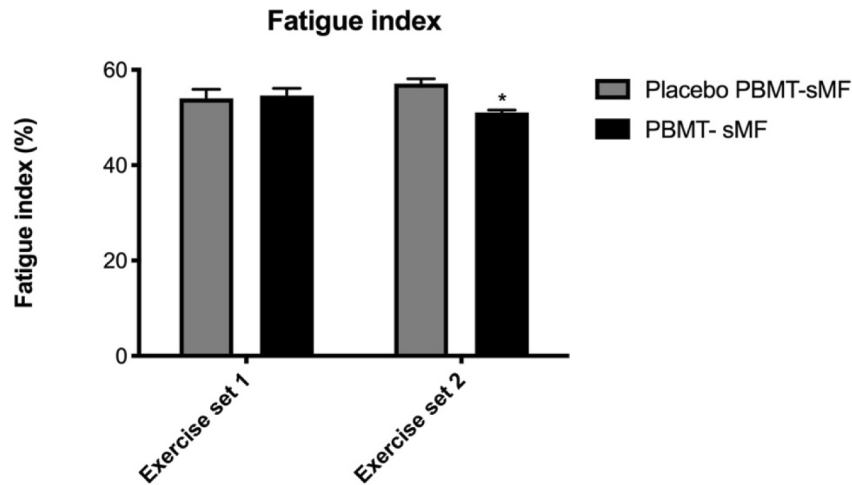

Fig. 3. Fatigue index. The data are presented in mean and SEM. * indicates statistical significance of $p < 0.05$ between interventions.

3.3. Secondary outcomes

There was no difference between interventions at first set (MD = 131.1, 95% CI - 947.0 to 1209) and second set of the exercise protocol (MD = 155.7, 95% CI - 922.4 to 1234) regarding total work (Fig. 4). In addition, there was no difference between interventions at first set (MD = - 0.96, 95% CI - 24.54 to 22.62) and second set of the exercise protocol (MD = 1.56, 95% - 22.02 to 25.14) regarding peak torque (Fig. 5).

There was no difference between interventions at baseline (MD = 0.20, 95% CI = -2.27 to 2.67) and also at first set of the exercise protocol (MD = - 0.46, 95% CI = - 2.93 to 2.01) regarding lactate levels (Fig. 6). In contrast, the PBMT-sMF decreased the lactate levels compared to the placebo PBMT-sMF post-intervention (MD = - 2.63, 95% CI = - 5.10 to - 0.16) (Fig. 6). The PBMT-sMF decreased the lactate levels compared to the placebo PBMT-sMF also at the second set of the exercise protocol (MD = - 2.77, 95% CI = - 5.25 to – 0.30) (Fig. 6).

All absolute values (mean and standard deviation) of primary and secondary outcomes separated by phases are provided in Table 2. We observed that there is no difference for any analyzed variable in phase 1 and phase 2, regardless of the intervention applied (PBMT-sMF or placebo).

In addition, all absolute values (mean and standard deviation) of primary and secondary outcomes are fully described in Table 3.
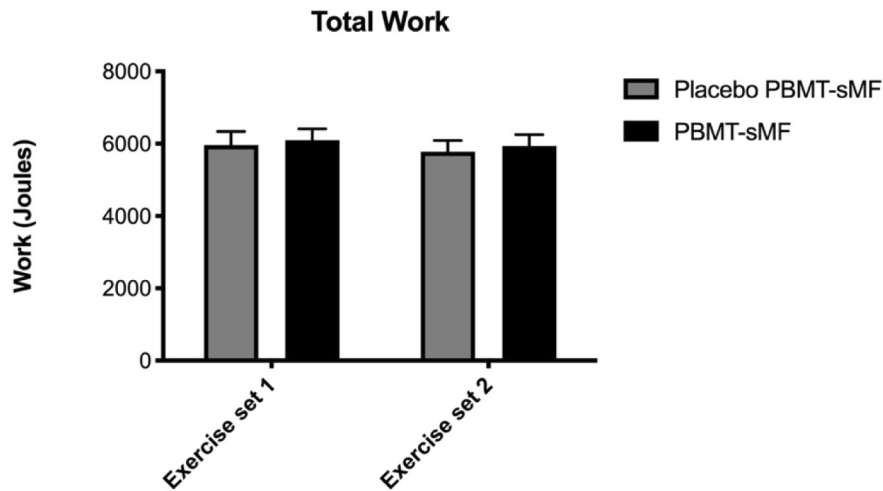
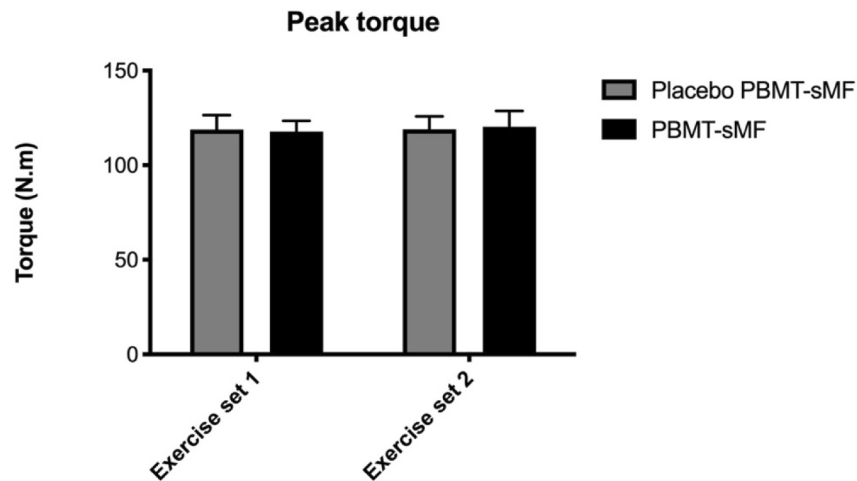**Fig. 4.** Total work. The data are presented in mean and SEM.

Fig. 5. Peak torque. The data are presented in mean and SEM.

Table 2. Absolute value of all outcomes by phases[a]

Outcomes	Time point	Phase 1 (n=12)	Phase 2 (n=12)
Fatigue index	Exercise set 1	54.45 (±5.85)	54.19 (±6.11)
	Exercise set 2	54.70 (±4.16)	53.50 (±4.13)
Total work	Exercise set 1	5911.18 (±1164.01)	6151.06 (±1202.73)
	Exercise set 2	5894.06 (±1075.95)	5817.03 (±1099.38)
Peak torque	Exercise set 1	117.47 (±24.40)	119.00 (±21.82)
	Exercise set 2	119.14 (±22.51)	120.03 (±30.00)
Lactate	Baseline	1.67 (±0.64)	1.47 (±1.05)
	Post-exercise set 1	10.14 (±2.50)	10.70 (±3.89)
	Post-intervention	9.08 (±2.34)	8.71 (±2.96)
	Post-exercise set 2	10.64 (±1.93)	11.27 (±3.44)

[a]The continuous variables are expressed as mean and standard deviation (±).
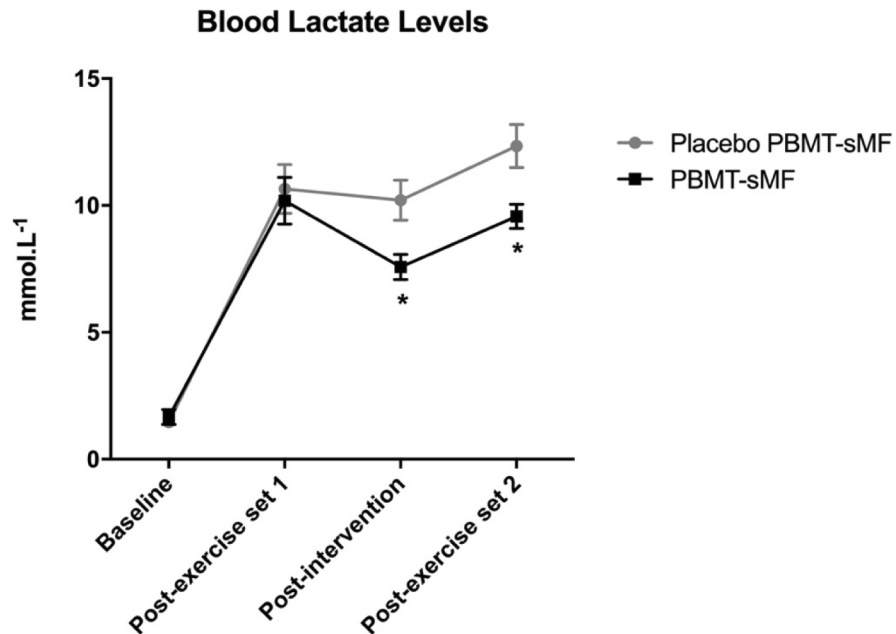
Blood Lactate Levels

Fig. 6. Blood lactate levels. The data are presented in mean and SEM. * indicates statistical significance of p<0.05 between interventions.

Table 3. Absolute values of all outcomes by treatments[a]

Outcomes	Time point	PBMT-sMF (n=12)	Placebo (n=12)
Fatigue index	Exercise set 1	54.62 (±5.26)	54.02 (±6.61)
	Exercise set 2	51.06 (±1.83)*	57.15 (±3.41)
Total work	Exercise set 1	6096.68 (±1078.27)	5965.55 (±1288.73)
	Exercise set 2	5933.41 (±1100.26)	5777.68 (±1070.39)
Peak torque	Exercise set 1	117.75 (±19.59)	118.71 (±26.23)
	Exercise set 2	120.37 (±28.89)	118.80 (±23.89)
Lactate	Baseline	1.67 (±1.04)	1.47 (±0.65)
	Post-exercise set 1	10.19 (±3.20)	10.65 (±3.34)
	Post-intervention	7.58 (±1.71)*	10.21 (±2.75)
	Post-exercise set 2	9.57 (±1.67)*	12.34 (±2.97)

[a]The continuous variables are expressed as mean and standard deviation (±). PBMT-sMF, photobiomodulation therapy combined with static magnetic field. * Indicates statistical significance of p<0.05 between interventions.

4. Discussion

This is the first randomized, crossover, triple-blinded placebo-controlled trial to assess the effects of PBMT-sMF, applied between two sets of exercises, on the subsequent physical performance. We observed that PBMT-sMF decreased the fatigue index at the second set of the exercise protocol. In addition, PBMT-sMF was able to decrease the lactate levels post-intervention and after the second set of the exercise protocol. Moreover, there was no difference between PBMT-sMF and placebo groups for total work and peak torque at the second set of the exercise protocol. Finally, we observed that there is no difference for any analyzed variable in phase 1 and phase 2, regardless of the intervention applied (PBMT-sMF or placebo). Therefore, we can infer

that there was no learning effect, so the crossover experimental design did not interfere on the results observed according to the tested treatment.

Several variables can be used to evaluate skeletal muscle fatigue, such as peak torque, total work and fatigue index, measured by isokinetic dynamometer during the exercise protocol, for example [12,26,31]. A recent systematic review included ten trials in a meta-analysis that demonstrated that PBMT or PBMT-sMF compared to placebo was able to decrease skeletal muscle fatigue when evaluated the isometric peak torque as a variable obtained from maximum voluntary contraction (MVC) test performed on isokinetic dynamometer [12]. In contrast, in our trial we found no difference between PBMT-sMF and placebo in peak torque and total work, however, we did not perform a MVC test to obtain these variables. On the other hand, a previous trial used the same variable evaluated in our trial, fatigue index, measured by isokinetic dynamometer during the exercise protocol. It was observed that, when PBMT was applied before a fatigue induced-protocol of the ankle plantar flexors, the fatigue index was decreased [31]. These findings corroborate our results, in which the PBMT-sMF was able to decrease the fatigue index at the second set of the exercise protocol. One possible reason why total work and peak torque were not affected in our trial could have been the time factor. However, a recent trial demonstrated that the ergogenic effects of PBMT-sMF were observed from 5 minutes to 24 hours after irradiation [21]. But, unlike our, in this trial the volunteers performed an eccentric exercise protocol, peak torque was obtained from MVC, and total work was not evaluated. Furthermore, the difference in the fatigue index founded in our trial may have been observed due to the sum of improvement, not statistically significant, in both peak torque and total work at the second set of the exercise protocol. However, further studies are needed to confirm this hypothesis.

In regards to lactate levels, the same systematic review previously aforementioned included twelve trials in a meta-analysis that demonstrated that PBMT or PBMT-sMF compared to placebo was effective in decreasing lactate levels when measured immediately or up to 5 minutes after exercise [12]. Our results corroborate this previous evidence, since, we also observed that PBMT-sMF decreased lactate levels 3 minutes after the intervention and 3 minutes after the second set of the exercise protocol. The decrease in lactate levels in a short amount of time observed in our trial may be related to the effect of PBMT and PBMT-sMF on the direct release of nitric oxide [32]. This release causes vasodilation, increasing microcirculation, which may have contributed to the removal of blood lactate [33]. Furthermore, the increase in microcirculation may also have contributed to increase the blood supply to the exercised muscles and, consequently, to increase the oxygen supply which led to a decrease in fatigue.

The PBMT-sMF irradiation protocol applied in our trial can be used before training to improve strength in post-injury rehabilitation, as previously demonstrated [15] and possibly may be used in detraining after a strength-training protocol [34]. Furthermore, our results demonstrated that, as previously described [15–21], PBMT-sMF as well as PBMT alone, can be considered an interesting intervention to decrease skeletal muscle fatigue and acts as an ergogenic agent. We observed through the fatigue index that PBMT-sMF was able to improve the volunteers' performance in the final third in relation to the first third of the second set of the exercise protocol performed [31]. In addition, PBMT-sMF was able to decrease the muscle activity catabolites from the second set of the exercise protocol, measured by means of lactate levels. These results demonstrate that PBMT-sMF has the potential to generate the maintenance of the performance in a prolonged period of exercise. That is, the application of PBMT-sMF in the intervals of an exercise can be used as a strategy to give small boosts during a prolonged physical activity. Therefore, we can suggest that the application of PBMT-sMF in the intervals of games or sports competitions, such as soccer, basketball, long jump and high jump competitions may be an interesting alternative to decrease skeletal muscle fatigue, generated by the cumulative effects of exercise without an adequate period of rest [1,4]. In this way, reducing performance loss throughout the game or sports competition.

This crossover trial used true randomization and concealment allocation to avoid selection bias. In addition, assessors, therapist and volunteers were blinded to avoid performance and detection bias. The crossover design was chosen to allow that each volunteer acted as his own control, eliminating among-volunteer variation. Moreover, the trial included a period of 7 days between interventions to reduce carryover effects. Finally, statistical analysis was conducted following intention-to-treat principles. On the other hand, although prospective registration of randomized controlled trials is not mandatory to publish in all scientific journals, we recognize that it is a limitation of our trial not to have been prospectively registered. In addition, we might consider that a limitation that this trial was carried out in a controlled environment and also with a controlled exercise protocol, instead of having been carried out in the real clinical sports scenario.

Further studies with rigorous methodological quality investigating the effects of PBMT-sMF on subsequent physical performance, on interval of games or competitions, carried out in the real clinical sports scene are needed. In addition, it is important to test the effects of PBMT-sMF in different types of exercises and sport activities. Finally, further studies analyzing different functional aspects and biochemical markers are needed as well.

5. Conclusions

PBMT-sMF is able to decrease skeletal muscle fatigue, accelerating post-exercise recovery and, consequently, increasing subsequent physical performance when applied between two sets of exercises.

Disclosures. ECPLJ: Multi Radiance Medical (F,C,P), DSJ: Multi Radiance Medical (I,E,P,R), SST has a personal relationship with ECPLJ. The remain authors declare no conflict of interest.

Data availability. Data underlying the results presented in this paper are not publicly available at this time but may be obtained from the authors upon reasonable request.

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