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ORIGINAL ARTICLE

Photobiomodulation therapy before futsal matches improves the staying time of athletes in the court and accelerates post-exercise recovery

Thiago De Marchi[1,2,3] · Ernesto Cesar Pinto Leal-Junior[4,5] · Kalvin Comin Lando[6] · Fabiane Cimadon[6] · Adriane Aver Vanin[5] · Darlan Pase da Rosa[2] · Mirian Salvador[1]

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Abstract
This study aimed to analyze PBMT effects on futsal player's performance and recovery in a non-controlled field environment. It is a randomized, triple-blinded, placebo-controlled, crossover clinical trial. The research included six professional athletes and in each match phototherapy treatments were performed before matches (40 minutes), blood samples were collected before treatments, and samples immediately after the end of the matches and 48 h after. Furthermore, videos were analyzed to quantify the time athletes spent on the pitch and the distance they covered. PBMT was performed at 17 sites of each lower limb (40 mins before matches), employing a cluster with 12 diodes (4 laser diodes of 905 nm, 4 LEDs of 875 nm, and 4 LEDs of 640 nm, 30 J per site). The performance of the athlete could be quantified considering the time on the pitch and the distance covered; the biochemical markers evaluated were creatine kinase, lactate dehydrogenase, blood lactate, and oxidative damage to lipids and proteins. PBMT significantly increased the time of staying in the pitch and a significant improvement in all the biochemical markers evaluated. No statistically significant difference was found for the distance covered. Pre-exercise PBMT can enhance performance and accelerate recovery of high-level futsal players.

Keywords Low-level laser therapy · Light-emitting diodes · Sport · Exercise · Phototherapy

Introduction

Futsal is an indoor adaptation of conventional soccer. Also known as indoor soccer, it was invented in 1934 at the Young Men Christians' Association in Montevideo, Uruguay, where it was first named "indoor-foot-ball." It has been recognized worldwide by the Fédération Internationale de Football Association (FIFA) since 1989 [1]. A futsal match is composed of two 20-min periods and a 10-min break. Some matches may take up to 80 min because the timer in futsal is stopped every time the ball leaves the pitch boundaries. This sport consists of intense physical activity with frequent bursts of high-intensity activity, such as attacking and defending movements/sprints, rapid direction changes with very short, low-intensity intervals (4–8 s), such as walking or running. Game preparation requires training in a combination of strength, power, agility, speed, aerobic and anaerobic, and endurance. Such intense acceleration/deceleration, brisk

✉ Thiago De Marchi
thiagomarchi@gmail.com

[1] Laboratory of Oxidative Stress and Antioxidants, Biotechnology Institute, University of Caxias do Sul, Caxias do Sul, RS, Brazil

[2] Faculty Cenecista of Bento Gonçalves (CNEC), Bento Gonçalves, RS, Brazil

[3] Postgraduate Program in Biotechnology, University of Caxias do Sul, Caxias do Sul, Brazil

[4] Postgraduate Program in Rehabilitation Sciences, Nove de Julho University (UNINOVE), São Paulo, SP, Brazil

[5] Laboratory of Phototherapy and Innovative Technologies in Health, Nove de Julho University (UNINOVE), São Paulo, SP, Brazil

[6] Academic Physical Therapy, Faculty Cenecista of Bento Gonçalves (CNEC), Bento Gonçalves, RS, Brazil

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direction change, and physical contact with other athletes expose players to muscular fatigue. Consequently, players may be prone to osteoarticular lesions [2].

Milioni et al. [3] claim that fatigue symptoms occur immediately after a match, which usually persist for a few days. Damage to large muscles, physiological stress, and muscle function impairment are commonly found among players, resulting in decreased performance and ability. Strategies should be employed to improve and speed up recovery after the games to better prepare the athletes for the next match.

Metabolism during contractile activity produces reactive oxygen species (ROS), which may lead muscles to develop oxidative stress. This may be a factor associated with reduced contractile function and muscular fatigue development [4]. Currently, injury prevention in competitive sport has been attracting more attention from the scientific community, committees, and athletes themselves. Using resources, such as photobiomodulation therapy (PBMT) [5], has gained increasing interest when employed to prevent and treat various diseases, such as muscular injuries, tendon injuries, and osteoarthritis, etc.

The first randomized clinical trial (RCT) investigating the use of photobiomodulation therapy (PBMT) for athletic performance enhancement was published 10 years ago by Leal-Junior et al. [6] only 2 years after the first animal study in this field was published by Lopes-Martins et al. [7]. This pioneer RCT showed for the very first time that the treatment with PBMT before an exercise session could enhance the performance of high-level volleyball athletes decreasing the onset muscle fatigue and preventing the expected increase of blood lactate levels. Currently, PBMT with lasers or light-emitting diodes (LEDs) has been proven to prevent skeletal muscle fatigue and speed up recovery [8–10].

A series of studies have shown that PBMT can reduce muscle fatigue and increase its contraction force and performance [4, 8–12]. PBMT may delay onset of fatigue, thereby improving athletic performance [8–10]. PBMT is a commercially available non-thermal modality [13] that may be used in a variety of clinical and athletic settings. The effects of PBMT are related to photochemical and photobiological effects within the tissue, which are not related to heat [13]. Non-thermal therapy modulates the biological processes of cells at the mitochondrial level. This increases oxygen consumption and adenosine triphosphate (ATP) production [13].

Several studies have shown the positive effects of PBMT on biochemical markers related to muscle damage and recovery [8], including blood lactate levels. In addition, PBMT decreases the necessary recovery time between exercise sessions [4, 11]. More recently, the literature has shown beneficial effects on muscle recovery if PBMT is applied using a combination of different wavelengths synergistically [14, 15]. This suggests that the combined use of different wavelengths may optimize cytochrome c oxidase modulation, which may increase PBMT effects [15].

Currently, most randomized clinical trials (RCTs) demonstrating the effectiveness of PBMT in increasing exercise performance and recovery acceleration have been conducted in a controlled environment such as laboratories or semi-controlled environment such as field tests [16]. To demonstrate the application and translation to the real world, this therapy must be tested in real competition settings and in different sports' modalities to confirm the findings previously observed in controlled laboratory tests. Thus, this study aimed to analyze PBMT effects on futsal players' performance and recovery in a non-controlled field environment.

Methods

Ethical aspects

This study was approved by the Committee of the Faculdade Cenecista of Bento Gonçalves, opinion number 055270/2015. In accordance with the Declaration of Helsinki, all subjects were advised regarding the procedure, and they signed an informed consent before participation in the study.

This study is a randomized, triple-blinded, placebo-controlled, crossover clinical trial. Six professional athletes of team Bento Gonçalves Futsal, who were competing on the gold series state championship, were selected for this study. Convenience sampling was employed based on the number of voluntary athletes. This was due to save research time and equal training routines among all participating athletes. The study was conducted in two different team matches in a time interval of approximately 2 weeks between the first and second interventions. The research team was present in each match to collect baseline blood samples, employ phototherapy protocol based on randomization, and perform other collections immediately after the end of the match and 48 h after. Furthermore, videos were analyzed to quantify the time that athletes spent on the pitch and the distance they covered (Fig. 1). All volunteers received information on all study procedures before the study was conducted. They also signed the consent form before be enroled in this trial.

The study included professional male athletes aged between 18 and 35 years, normotensive, eupneic, with normal heart rate. They did not have a history of musculoskeletal injury in the hip and knee regions 2 months before the study. They remained on the pitch for a minimum of 9 min, and they did not use pharmacological agents and/or nutritional supplements and participated with a minimum frequency of 80% of the team training sessions. Athletes who did not meet the aforementioned criteria, those who had musculoskeletal injury during the study, and those who may have their training routine changed during the study for any reason were also excluded from this study.

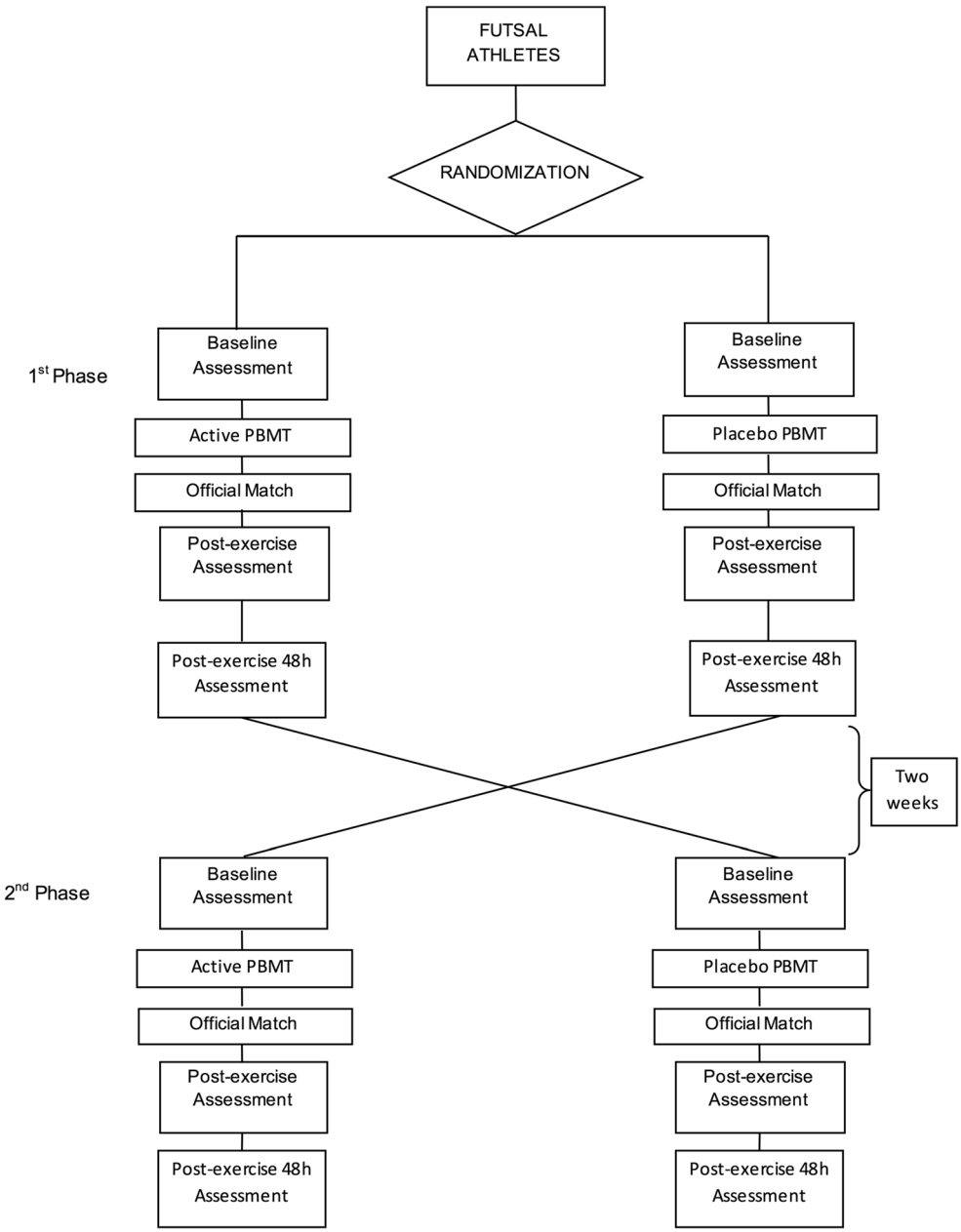


Fig. 1 Consort flowchart summarizing study procedures

Randomization and blinding procedures

The six team volunteers were randomly separated into two experimental groups of three volunteers each. Randomization was performed through a simple drawing of lots (A or B) prepared in opaque envelopes, which determines whether a volunteer receives active phototherapy in the first or second match. The volunteers who drew lot A received effective and placebo phototherapy in the first and second matches, respectively, whereas the volunteers who drew lot B received placebo and effective phototherapy in the first and second matches, respectively. The laser unit used in the study emitted the same sounds regardless of the programmed mode (effective or placebo). Randomization was conducted by a participating researcher who was in charge of programming the laser device in accordance with the randomization result. This researcher was instructed not to communicate the treatment type administered to any of the other researchers involved in the study until its end. Similarly, the researcher responsible for employing phototherapy did not know the phototherapy type (effective or placebo) that was being used with the volunteers.

Photobiomodulation therapy

The phototherapy protocol was conducted in the same way in both interventions. After randomization, athletes underwent phototherapy 40 min before they entered the pitch. Twelve clusters with 12 diodes were used for phototherapy. Four

905-nm diodes (0.3125-mW mean power, 50-W peak power for each diode), four 875-nm diodes (17.5-mW mean power for each diode), and four 640-nm diodes (15-mW mean power for each diode) were used. They were manufactured by Multi Radiance Medical® (Solon, OH, USA). This device was chosen by the research team due to its high quality and reliability [15]. Both effective application and placebo were performed using the cluster in direct contact with the skin, with light pressure and in a stationary way in an isolated environment. This was performed in the presence of the volunteer and the researcher responsible for implementation only (Table 1). A protection with opaque googles was used by the athletes not to identify whether administration was placebo or effective. It must be pointed out the device does not produce any thermal sensation in the patient's skin, and the sounds were emitted regardless of the way phototherapy was administered. Phototherapy was performed at nine different knee extensor and hip flexor muscle locations, six knee flexor muscle and hip extensor muscle locations, and two plantar flexor muscle locations of both lower limbs. Administration areas were selected based on studies previously performed using this same device [15–18]. The irradiation locations are illustrated in Fig. 2, and 17 sites of each lower limb were irradiated. Each site of irradiation received a 30-J dose delivered in 228 s (3 min and 48 s per site).

Table 1 Parameters for PBMT

Number of lasers	4 super-pulsed infrared
Wavelength (nm)	905 (± 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 laser (cm^2)—each	0.44
Number of red LEDs	4 Red
Wavelength of red LEDs (nm)	640 (±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 red LED (cm^2)—each	0.9
Number of infrared LEDs	4 Infrared
Wavelength of infrared LEDs (nm)	875 (±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 LED (cm^2)—each	0.9
Magnetic field (mT)	35
Irradiation time per site (sec)	228
Total dose per site (J)	30
Total dose applied per lower limb (J)	510
Aperture of device (cm^2)	20
Application mode	Cluster probe held stationary in skin contact with a 90° angle and slight pressure

Video analysis

Video recording of the games played by the team were used by the research team to measure the time and distance in pitch, by numbering the shirt each athlete used on the pitch. The distance covered by each athlete on the pitch was measured based on Withers et al. [19], who used footage of the athletes through 9 m in five different types of movement: walking, trotting, running, and lateral and backward movements. After filming, the space traveled was divided by the number of steps to determine each athlete's length of step in different forms of travel. Pitch time was collected by measuring the time each athlete was on the pitch, with the ball in play [19]. The researcher involved in the video analysis was blind to all other methodological steps.



Fig. 2 **a** Treatment points in knee extensor muscles. **b** Treatment points in knee flexor and ankle plantiflexor muscles

Blood samples and biochemical assays

Blood samples were collected by a qualified nurse blinded to group allocation and were obtained from an antecubital vein before exercise and exactly 5 min, 60 min, 24 h, 48 h, and 72 h after the end of the exercise protocol. Blood was centrifuged at 2700×*g* for 10 min at 4 °C. Serum was immediately pipetted into Eppendorf tubes and stored at − 80 °C until analysis. Lipid damages were measured spectrophotometrically (Shimadzu spectrophotometer Model UV-1700, Shimadzu®, Japan) by determining thiobarbituric acid reactive substances (TBARS), as previously described by Wills [20]. Results were expressed as nmol/ml. The oxidative damage to proteins was assessed by determining carbonyl groups based on the reaction with 2,4-dinitrophenylhydrazine (DNPH), as previously described by Levine et al. [21]. Results were expressed as DNPH nmol/mg of protein. Total protein levels were evaluated using the total protein kit from Labtest® (Protein Kit, Labtest Diagnostica S.A., Brazil). The concentration of L-lactate was measured by enzymatic activity of lactic dehydrogenase (LDH), which forms NADH. It was measured in UV at 340 nm. LDH concentration was determined by a kinetic reaction that assessed NADH decomposition speed. A decrease in resorption was assessed at 340 nm. The activity of creatine kinase-MB fraction was evaluated by inhibiting M-fraction activity using a specific antibody. Consequently, it inhibited MM fractions and the fraction M of MB. Starting from the assumption that the BB dimer is virtually nonexistent in peripheral blood, the residual enzymatic activity corresponds to fraction B of CK-MB only. With regard to the NADP+ reduction speed, NADPH is proportional to the activity of CK in the sample. All laboratory analyses were performed at the laboratory of Clinical Analyses of the Non-Profit Bento Gonçalves College using a Mindray BS-120 chemistry analyzer employing protocols and BioClin Quibasa reagents and controls.

Statistical analysis

Data are expressed as mean and SD in text and as mean and SEM in the figures. To analyze data, levels of CK, TBARS, CP, LDH, and lactate were considered in blood samples collected before, immediately after, and 48 h after a match. The time on pitch and the distance covered by the athletes on the pitch were also taken into account. The values obtained for each variable will undergo the Shapiro–Wilk normality test. Based on randomization, variables were compared using *t* test (time on pitch and distance covered) and analysis of variance, with repeated measurements for the factors of time of collections, as well as testing between- and within-group differences (followed by a post hoc Bonferroni test). The SPSS 17.0 software was used for the statistical analysis, with a significance level of 5% ($p < 0.05$). Magnitude-based inference analyses were also used to examine practical significances. The magnitude of differences (Cohen-d) between groups was calculated using the mean and SD of placebo and PBMT treatments (using Gpower 3.1). We adopted the criteria of Cohen for the analysis (0.2: small; 0.50: moderate; 0.80: large).

Results

Six healthy male, futsal athletes that met the inclusion criteria participated in this study. The athletes' mean age was 26.16 ± 6.91 years.

In this study, the performance of the athlete could be quantified considering the time on the pitch. A statistically significant difference ($p < 0.05$) was found between placebo treatment (23.44 ± 5.71 min) when compared to PBMT (29.15 ± 10.92 min), as shown in Fig. 3a. No statistically significant difference was found for the distance covered by the athlete on the pitch. This variable was analyzed by comparing placebo treatment (2317.89 ± 786.79 m) with PBMT (2409.92 ± 613.44 m). Considering placebo tratment performance as 100%, we have a performance increase of 24.71% in time on the pitch and 3.97% in distance covered.

The lactate analyses are shown in Fig. 3b. A statistically significant difference ($p < 0.01$) was found among pre- (15.33 ± 2.88 mmol/l^{-1}), post, and post 48-h collections (30.63 ± 11.29 and 22.73 ± 6.87 mmol/l^{-1}) in placebo treatment. Moreover, a statistically significant difference ($p < 0.01$) was

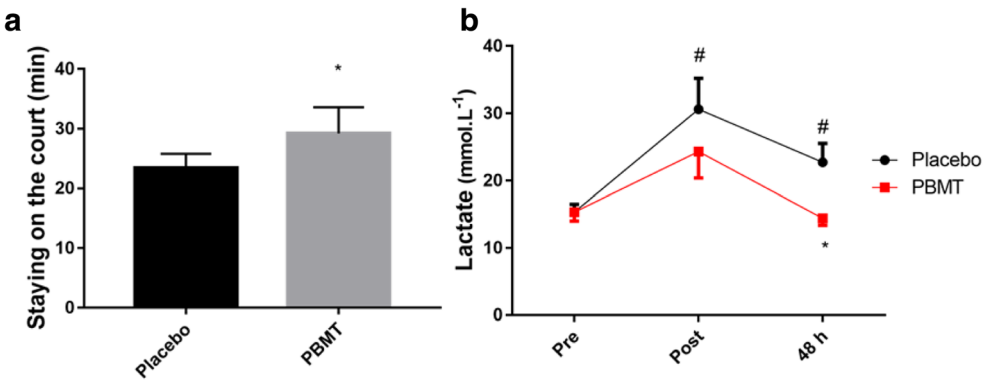


Fig. 3 **a** *Statistically significant difference in comparison between the placebo and photobiomodulatoin treatments ($p > 0.05$). **b** #Statistically significant difference in comparison with the pre ($p < 0.05$),

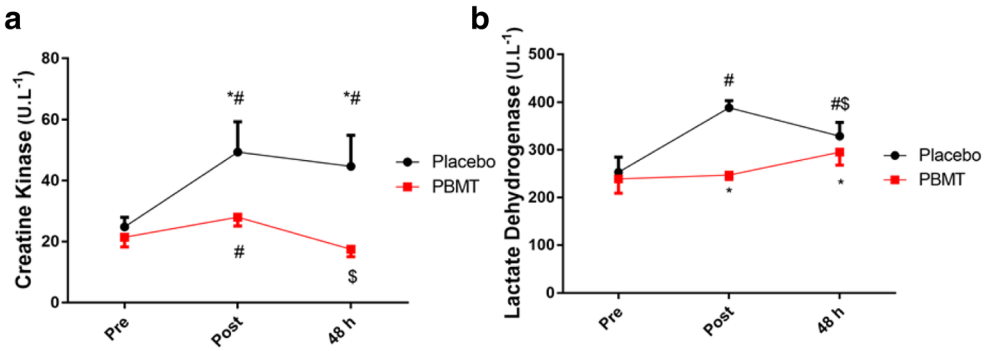


Fig. 4 **a, b** #Statistically significant difference in comparison with the pre ($p < 0.05$), $ statistically significant difference in comparison with the post and 48 h ($p < 0.05$), *statistically significant difference in comparison between the placebo and photobiomodulation groups

found after comparing post 48-h collection in placebo treatment (22.73 ± 6.87 mmol/l^{-1}) and post 48-h collection in PBMT (14.40 ± 2.58 mmol/l^{-1}). Considering the concentration of lactate pre-collection in the placebo treatment as 100%, we have an increase of 99.80% in post-match and 48.27% in 48 h for the placebo treatment. In the PBMT, an increase of 58.71% in post-match and a decrease of 6.07% in 48 h are observed.

With regard to CK analysis results (Fig. 4a), a statistically significant difference ($p < 0.05$) was found among pre-collection (24.8 ± 7.75 U/l), post-collection, and post 48 h (49.33 ± 24.37 U/l and 44.69 ± 24.91 U/l, respectively) in the placebo treatment. In addition, statistically significant differences ($p < 0.05$) were found between post-collection and post 48 h (27.95 ± 7.17 and 17.46 ± 5.96 U/l, respectively) in the photobiomodulation group (PBMT). A statistically significant difference ($p < 0.05$) was found after comparing enzyme levels of post-match and post 48 h of placebo treatment (49.33 ± 24.37 and 44.69 ± 24.91 U/l, respectively) and PBMT (27.95 ± 7.17 and 17.46 ± 5.96 U/l). Considering the concentration of CK pre-collection in the placebo treatment as 100%, we have an increase of 98.91% in post-match and 80.20% in 48 h for the placebo treatment. In the PBMT group, an increase of 30.61% in the post-match and a decrease of 18.41% in 48 h are observed.

The LDH analysis (Fig. 4b) revealed a statistically significant difference ($p < 0.05$) among pre-collection (253.00 ± 78.19 U/l), post-match, and post 48-h collections (388.40 ± 36.52 and 328.67 ± 70.85 U/l) in placebo treatment. Another statistically significant difference ($p < 0.05$) was found between the post-match and post 48-h collections of placebo treatment. A statistically significant difference ($p < 0.05$) was also found between the comparison of LDH enzyme levels of post- and post 48-h samples of placebo treatment and PBMT (247.08 ± 22.75 and 295.20 ± 65.88 U/l). Considering the concentration of LDH pre-collection in the placebo treatment as 100%, we have an increase of 53.52% in post-match and 29.91% in 48 h for the placebo treatment. In the PBMT, an increase of 3.45% in the post-match and 23.60% in 48 h is observed.

The biochemical marker concentrations of oxidative damage to lipids, as shown in Fig. 5a, indicate that a significant decrease in the concentration of TBARS in PBMT post-collection (3.30 ± 0.43) was found after treatment compared with pre-collection (3.58 ± 0.35) and placebo treatment (3.96 ± 0.44) ($p < 0.05$). Considering the concentration of TBARS pre-collection in the placebo treatment as 100%, we have an increase of 2.78% in post-match and a decrease of 9.60% in 48 h for the placebo treatment. In the PBMT, a decrease of 7.82% in the post-match and 3.35% in 48 h is observed. In

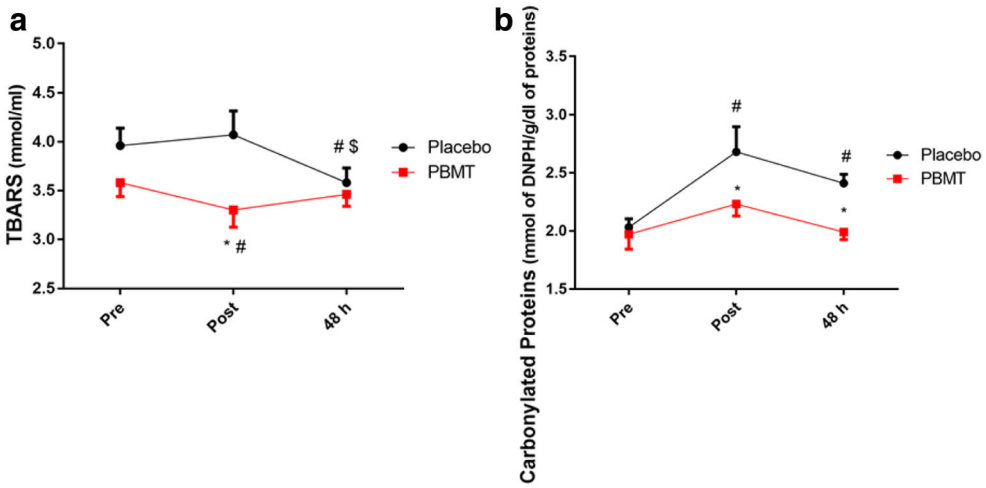


Fig. 5 **a** #Statistically significant difference in comparison with the pre ($p < 0.05$), $ statistically significant difference in comparison with the post and 48 h ($p < 0.05$), *statistically significant difference in comparison between the placebo and photobiomodulation groups. **b** #Statistically significant difference in comparison with the pre ($p < 0.05$), *statistically significant difference in comparison between the placebo and photobiomodulation groups

addition, our results of biochemical marker concentrations of oxidative damage to proteins indicate a significant decrease in concentrations of CP in the PBMT compared with the placebo treatment ($p < 0.05$) as shown in Fig. 5b. Considering the oxidative damage to proteins in pre-exercise samples in the placebo treatment as 100%, we have an increase of 32.02% in post-match and 18.72% in 48 h for the placebo treatment. In the PBMT, there is an increase of 13.20% in the post-match and 1.02% in 48 h. In addition, Table 2 shows the effect sizes for all analyzed variables.

Discussion

The aim of this study was to verify the effectiveness of phototherapy (PBMT) as a preventative resource against fatigue and muscle damage when administered before an official futsal match. Considering this is a sport increasing in popularity and played in competitive environment, and ever-increasing levels, numerous factors may interfere in the outcomes of matches [2, 3]. Technical issues and peculiar choices made by the technical staff for some athletes require them to be in optimum shape to cope with sustained exertion with minimal rest periods. Furthermore, emotional and psychological factors, such as personal demands, goals, and family pressure may directly interfere with an athlete's performance on the pitch [1]. This study's results reveal that phototherapy may be an alternative to prevent athletes from experiencing fatigue and muscle damage caused by this highly competitive sport.

Current studies [8–10, 15, 22, 23] suggest that previous use of PBMT has positive effects on maintaining muscle condition during physical activity and improving muscle recovery after exercise. However, most of these clinical trials were performed in a controlled environment laboratory. In this study, the possibilities of practical implementation of this tool were investigated, considering the sport scenario.

In a study conducted by Ferraresi et al. [24], results showing the effectiveness of preventative phototherapy in male volleyball athletes in real competition situations were found to inhibit the expected increase of CK enzyme activity in the bloodstream 24 h after the match. This study used four different doses, and one of them was a placebo. The study found that the doses 210 J and J 315 were effective in preventing the increase in CK enzyme activity in the bloodstream. However, this study does not monitored any aspect related to athletes' activity during the matches such as the number of jumps or spikes performed or the pitch time for each athlete during each match analyzed. Without data related to athletes' activity, it is not possible to infer that the variation in CK is reliable. Furthermore, a letter to the editor [25] about this article raised serious doubts and concerns about the methodological design and the statistical analysis, invalidating its findings.

Compared with these results, this study shows that the effective application of PBMT was also able to promote a reduction in the blood concentrations of muscle damage and oxidative markers comparing placebo and PBMT, and all athletes participated assiduously in matches. In addition, to measuring the real benefits of preventative phototherapy as a way of reducing muscle fatigue in athletes, this study found aspects wherein PBMT played a role in the improvement of athletes' performance. This statement is based on the comparison between placebo and PBMT regarding time on the pitch of athletes during the matches.

Some authors state that the response to oxidative damage in athletes is higher than in sedentary individuals [26]. In this study, such placebo treatment response is found in post 48-h assessments due to the similarity with the pre-exercise situation. However, the same athletes who participated in the

Table 2 The magnitude of differences between groups

		Percentage of change compared to placebo	Cohen-d	Effect rating
CK	Post-match	–43.34	1.1902	Large
	Post 48 h	–60.93	1.5029	Large
LDH	Post-match	–36.39	4.6449	Large
	Post 48 h	–10,18	0.4892	Moderate
TBARS	Post-match	–18.92	1.4751	Large
	Post 48 h	–3.35	0.3562	Small
CP	Post-match	–16.79	1.0859	Large
	Post 48 h	–17.43	2.3912	Large
Lactate	Post-match	–20.57	0.6170	Moderate
	Post 48 h	–36.65	1.6052	Large
Time on pitch	–	24.71	0.6553	Moderate
Distance covered	–	3.97	0.1304	Small

CK creatine kinase, *LDH* lactate dehydrogenase, *TBARS* oxidative damage to lipid, *CP* oxidative damage to protein

effective PBMT displayed faster defense responses to oxidative damage caused by exercise. Therefore, considering previous results associated at the laboratory level [4], it is evident that PBMT plays an important role in redox regulation of muscle metabolism, whether it is basal or after adverse stimuli generated by inflammatory processes, among other micro- or micro-damage consequences.

The non-thermal PBMT has a modulating effect on cytochrome c oxidase activity, and it may explain how PBMT improves performance while protecting the skeletal muscle from exercise-induced damage. This has been considered as the key mechanism in the light-tissue interaction, which increases cellular metabolism by increasing mitochondrial function [27]. Recently, Albuquerque-Pontes et al. [28] have shown that a single PBMT irradiation can increase cytochrome c oxidase activity in intact skeletal muscle up to 24 h after irradiation, and this is dependent on the dose and the wavelength used. In fact, the use of three wavelengths synergistically can lead to optimized outcomes in exercise performance enhancement since different wavelengths have different time-response windows in intact (non-injured) skeletal muscles [28]. Therefore, only the simultaneous use of three wavelengths in different bands of spectrum (from red to near infrared) can enhance cytochrome c oxidase activity, and consequently mitochondrial function and ATP production, from 5 min to 24 h after irradiation, which gives us the rationale to use a device that allows the simultaneous use of three wavelengths.

Lactate is another frequently used marker to indirectly monitor muscle recovery performance. The concentration of lactate in the blood is considered an important marker of muscular acidosis, and it is often monitored in sports environments, particularly in high-intensity sports [29–31]. Higher levels of this marker should be and were expected in PBMT group since athlete's performance was significantly better. Thus, it is reasonable to say that active PBMT prevented the expected increase in blood lactate levels, reduced muscle fatigue, and led to quicker recovery after exercise, supporting previous findings [4, 32, 33].

Athletes' enhanced stay on the pitch may be directly correlated with the fact that PBMT was able to delay the process of muscle fatigue in athletes during a futsal match. Despite this, with longer activity time, the damage caused by strenuous physical exercise was reduced 48 h after the match. Thus, the head coach might possibly take technical and tactic actions with more decisive athletes for longer periods during matches, leading to a better performance to the futsal team in a general way. In Table 2, we can observe positive effects in favor of the use of PBMT for all the variables analyzed, even in the variable distance traveled, which we did not find statistically significantly difference. However, its is important to highlight that in high-level sports activities an average improvement of 3.97% in performance can be the difference between win or lose.

This study has a complex organization because it investigated an official competition, and the researchers attempted to respect the official team planning as much as possible. Some limitations need to be considered, such as the final number of participating athletes based on the proposed methodological choices and the freedom of choice of the team's technical committee. In addition, only one PBMT treatment session was performed (40 min before matches), and previous studies [12, 23, 34] showed that treatment sessions subsequent to activity may be beneficial in muscle recovery. As a result, the combination of sessions (pre and post) may still enhance the effects found, considering the athletes' muscle recovery level. Finally, this study's results demonstrate the potential use of PBMT as a prophylactic strategy for the performance and improvement of high-level athletic recovery, and this seems to be a relevant advancement in the evidence to the clinical use of this therapeutic tool.

Conclusion

In summary, preventative implementation of PBMT in professional futsal players appears to be effective in preventing fatigue and muscle damage. Consequently, it accelerates muscle recovery and improves the performance of athletes who remain on the pitch for the longest period of time. Finally, further studies are needed to verify the effects of PBMT in different sports modalities in order to make this therapy wide used as an ergogenic agent.

Compliance with ethical standards

Competing interests Professor Ernesto Cesar Pinto Leal-Junior receives research support from Multi Radiance Medical (Solon, OH, USA), a laser device manufacturer. Multi Radiance Medical had no role in the planning of this study. They had no influence on study design, data collection and analysis, decision to publish, or preparation of the manuscript. The remaining authors declare that they have no conflict of interests.

Ethical aspects The study was approved by the Ethics Committee of the Faculdade Cenecista of Bento Gonçalves. In accordance with the Declaration of Helsinki, all subjects were advised about the procedure and they signed an informed consent prior to participation in the study (CAEE 46096015.4.0000.5571).

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