



ORIGINAL ARTICLE

# Effect of Low-Level Laser Therapy on Muscle Strength and Endurance and Post-Exercise Recovery of Young Adult: A Double-Blind, Placebo-Controlled, Randomized Clinical Trial

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## ABSTRACT

**Background.** Recovery or post-exercise rehabilitation is an essential part of exercise training. Low-level Laser Therapy (LLLT) is a modality increasing interest for recovery because of having a conservative and non-aggressive method. LLLT also decreases the production of fatigue-related biomechanical markers, such as lactate, C-reactive protein (CRP), and Creatine kinase (CK). **Objectives.** To investigate the effect of low-level laser therapy on muscle strength and endurance and post-exercise recovery of young adults between 20-35 years old. **Methods.** Fifty subjects were enrolled in this double-blind, placebo-controlled, randomized clinical trial study. Three days after the familiarization session, the subjects were divided into two groups via block randomization: the first group received pre-exercise laser at 810 nm, 60mW, and 60Hz frequency for 30 seconds on three point's rectus femoris muscle. The other group received a placebo laser on the same points. The operator who was blinded to the allocation of the subjects applied the phototherapy. They underwent an exercise test with a treadmill and a maximum number of knee extensions with a 10 Kilograms (Kg) weight. The test results, level of blood lactate, perceived exertion of fatigue, and muscle soreness were assessed, and the results were analyzed. **Results.** The blood lactate level, the severity of muscle pain, the perceived exertion of fatigue, and the repetition of knee extensions with a 10 kg weight, had a statistically significant difference between laser and placebo groups ( $p < 0.05$ ). **Conclusion.** The use of LLL before exercise may improve muscular performance and reduce muscle soreness and fatigue.

**KEYWORDS:** *Low-Level Laser Therapy (LLLT), Muscle Performance, Muscle Fatigue.*

## INTRODUCTION

Since the 1960-decade, Low-level laser therapy (LLLT) has been used for the healing of different injuries such as soft tissues (1-5), bones (6-8), and nervous tissues (9-14). In the last decade, several studies have investigated the positive effects of LLLT on muscle performance and fatigue (15-19). Recovery after exercise plays an essential role in injury prevention in sports

medicine. Fatigue decreases the speed and the power of muscle contractions and the level of exercise performance (15, 16). It also increases the blood markers that are related to muscular damages, such as Creatine kinase (CK), C - reactive protein (CRP), and Lactate dehydrogenase (LDH) (16-18). Therefore, post-exercise recovery effectively increases pain relief,

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inflammation subsidence, and acceleration of the repairing process in the damaged tissues (16). Different investigators have used various rehabilitation modalities, including Non-Steroidal Anti-Inflammatory Drugs (NSAID), ultrasound, homeopathy, acupuncture, electrotherapy, massage, and cryotherapy (16, 17). Low-level laser therapy, LLLT, has been used as a new treatment to prevent injuries and control muscle soreness (16, 17). The suggested mechanism of LLLT action is the stimulation of the mitochondrial system and the effect on cytochrome C oxidase that enhances muscle power due to the acceleration of ATP production, leading to fatigue delay and protection of muscle against injury (18, 19). LLLT decreases the production of fatigue-associated markers such as LDH, CRP, and CK (19) and, by enhancing the oxidase system, reduces oxidative stress and elevates muscle buffering capacity (20-22).

Different investigators have studied the effects of LLLT on muscle performance and fatigue, suggesting various protocols regarding the wavelength, power density, irradiation time, and light sources of the laser, with an apparent inconsistency among the results (23). By considering previously reported results, this study aimed to investigate the effectiveness of the LLLT on muscle performance and fatigue among young adults. The wavelength of 810 nanometers (nm) used in this study is widely used in practice but has rarely been investigated in previous studies.

## MATERIALS AND METHODS

**Study Design and Protocol.** Subjects who fulfilled the inclusion criteria were enrolled in the study after signing informed consent and being fully informed about the study protocol. This trial is registered on the Iranian Registry of Clinical Trials (IRCT) website under the trial code IRCT20200415047097. The ethical committee of Shahid Beheshti University of Medical Sciences approves this trial under the ethical code IR.SBMU.MSP.REC.1397.459.

**Subjects.** The participants were fifty volunteers (31 male and 19 female) aged 20-35, referring to the sports medicine ward of Taleghani hospital during the year 2018 that met the inclusion criteria. Participants were enrolled in the trial after being invited and explained about the trial process by sport medicine residents and signing the informed consent.

**Inclusion and Exclusion Criteria.** The inclusion criteria were age in the range of 20-35, being sedentary (no history of regular exercise during the past three months), no history of professional sport during the lifetime, not consuming any drug or supplements, and no musculoskeletal disorder that prevents the use of treadmill or weight.

The exclusion criteria were being in the menstrual period in women, withdrawal from participating in the study

**Familiarization Session.** Three days before the experiment, the subjects underwent an exercise test with a treadmill and a maximum number of knee extensions with a 10 Kilograms (Kg) weight.

**Study Protocol.** After explaining the subjects' study procedure and signing informed consent, subjects were enrolled in the trial. In the familiarization session, a form in which they were asked about demographic data, medical and activity history was filled by the participants. Then 5 minutes warm-up as treadmill walking with 2-3km/h was done.

**Resistance Test.** After warming up, a resistance test was done, as the maximum number of knee extensions in the full range of motion with a 10 Kg weight machine (brand JK EXER, made in Taiwan) and the results (the maximum number of knee extensions) were recorded.

**Aerobic Test.** After the resistance test, the aerobic test was performed as a vigorous session of running on a treadmill (brand AVECINNA, made in Iran) with an intensity of 80-90% of the reserve heart rate for 15 minutes. Then cool-down phase as 5 minutes walking at 3-4 km/h and hamstring stretching for 20 seconds were done. Subjects were asked not to have exercise at home for three days after the test.

Immediately after exercise, the blood lactate level was measured by a lactometer (brand ECF, made in Italy) and lactometer kit (brand Sensal, no 74, made in China), using a fingertip blood sample. The blood sample was collected by puncturing the fingertip using a lancet (brand Ava, made in Iran). The Subjects were asked to rate their feeling of fatigue by RPE (Rating of Perceived Excretion) scale from 6 (minimal fatigue) to 20 (exhaustion). One hour later, the lactate test was repeated, and the results were recorded.

A telephone interview was done 24 hours later, and the subjects were asked about having any muscle soreness. If they felt any pain, they were asked to rate the severity of it from 1 (the

least pain) to 10 (the most severe pain) By VAS (Visual Analog Scale) score.

Three days later, the subjects were randomly divided into two groups: the treatment group received one session of the real laser at 810nm wavelength, 60 mW power, 60 Hz frequency by a laser device (brand MPTC, model LMPT 200, made in Iran) on 3 points of rectus femoris muscle, 30 seconds on each point (Figure 1), when the subject in the supine position. In the control group, the device was off, and a probe with no laser (placebo) on the same points was applied. As a landmark, the distance between the Anterior Superior Iliac Spine (ASIS) to the upper border of the patella was divided into 3 equal regions, and the middle point of every region was considered as an irradiation point. The aerobic and the resistance tests and evaluations were repeated. The results were measured and analyzed. Figure 2 indicates the study design.

**Primary and Secondary Outcomes.** The primary outcome was the maximum number of complete knee extensions with a 10 kg weight and the blood level of lactate (measured by the lactometer). The secondary outcome was fatigue (measured by RPE scale) and muscular pain (measured by VAS score).

**Sample Size Calculation.** The sample size was determined based on a previous study with a similar protocol, done by Feraressi et al. on 40 participants (24) with  $\alpha = 5\%$  and  $\beta = 20\%$  and effect size of 95%. 25% of the sample size was added to it due to the probability of sample loss. The total number of the sample was set 50, 25 in each group, and it was sufficient for this trial.

**Randomization.** Block randomization was performed to minimize the risk of selection bias. The participants, according to their Body Mass Index or BMI, were divided into two subgroups

of BMI less than 25 (22 participants) and BMI equal to 25 or more (28 participants). Randomization was carried out in each subgroup separately, with a block size of 4. 2 cards of A and two cards of B were shuffled and randomly put together and the operator of the randomization, according to the order that the cards were arranged, assigned the participants to groups A or B. The participant who had received card A was placed in group A and received a real laser, whereas the participant who had received card B was placed in group B and received a placebo. The trial operators carried out all of the randomization steps. The participants and the operators of randomization did not know to which group A and B cards belong.

**Blinding.** Double-blinding was done to avoid performance bias, meaning that the participant did not know which group is settled. The operator was unable to differentiate between active and placebo laser. The laser device was programmed by a nurse who was not in contact with the participants. Then a second operator who was blinded to the allocation of the subjects applied the phototherapy. The laser device was where the operator could not see whether it is on or off.

**Data Analysis.** For statistical analysis, SPSS version 16 was used. Statistical tests as a t-test, Shapiro-Wilk test, and Wilcoxon test was also done on the data. A P-value of less than 0.05 was considered significant.

## RESULTS

This study was performed on 50 sedentary participants in Taleghani Hospital, the sports medicine ward. Subjects were accidentally divided into two groups containing 25 persons as real or placebo laser groups (Table 1).

Table 1. Demographic Information of Participants

	Treatment Group	Placebo Group
Age	22.92 ± 4.06	24.8 ± 2.41
Gender		
Male	17 (68%)	14 (56%)
Female	8 (32%)	11 (44%)
Height	1.73 ± 0.78 m	24.4 ± 3.66
Weight	77.3 ± 9.3	72.09 ± 6.62
Body Mass Index (BMI)	25.4 ± 1.95	25.6 ± 1.96

**The Effect of Laser on Blood Lactate Level in Treatment and Placebo Groups.** The paired t-test was used to assess the effect of laser on the lactate level in the 2<sup>nd</sup> session immediately after exercise in both the placebo and treatment groups.

The result showed a significant difference between blood lactate level in real laser and placebo laser groups ( $p = 0.018$ ) (Table 2).

**The Effect of Laser on the Number of Weight Repetitions in participants in Treatment and**

**Placebo Groups.** A paired t-test was used to assess the effect of laser on the maximum number of knee extensions with a 10 kg weight in participants in

treatment and placebo groups, and the result showed a significant difference between real laser and placebo groups ( $p = 0.018$ ) (Table 2).

**Table 2. Effect of Laser on Lactate Level, Weight Repetition, Fatigue and Muscle Pain in Both Treatment and Placebo Groups**

	Max	Min	Mean $\pm$ SD	P-Value Shapiro-wilk Tst	P-Value of Paired T-Testt	P-Value of Wilcoxon Test
<b>Lactate level in the 2<sup>nd</sup> session</b>					<b>0.018</b>	
Treatment	17.41	4.76	11.23 $\pm$ 3.43	0.687		
Placebo	16.49	2.01	8.68 $\pm$ 3.82	0.58		
<b>Weight repetition 2<sup>nd</sup> session</b>					<b>0.018</b>	
Treatment	16	9	12.52 $\pm$ 1.82	0.162		
Placebo	16	8	11.36 $\pm$ 2.41	0.111		
<b>Fatigue perception(RPE) 2<sup>nd</sup> session</b>						<b>P-value &lt; 0.001</b>
Treatment	14	8	10.96 $\pm$ 1.24	0.045		
Placebo	17	13	14.76 $\pm$ 1.28	0.048		
<b>Muscle pain(VAS score) 2<sup>nd</sup> session</b>						<b>P-value &lt; 0.001</b>
Treatment	5	2	3.12 $\pm$ 0.83	0.003		
Placebo	10	3	5.08 $\pm$ 1.55	0.008		

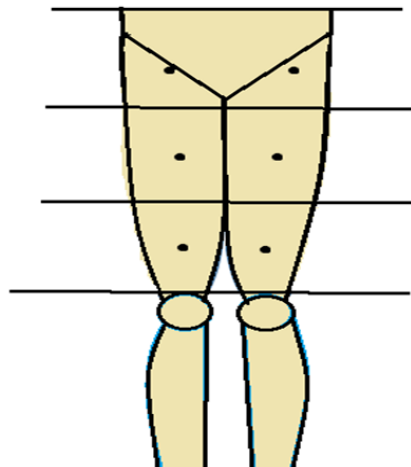
**The Effect of Laser on Fatigue in Participants in Treatment and Placebo Groups.** Fatigue perception was measured subjectively by each participant by using the RPE scale, scoring 6 (no fatigue) to 20 (exhaustion).

Wilcoxon test was used to assess the effect of laser on fatigue perception in participants in both groups in the 2<sup>nd</sup> session, and the result showed a significant effect of laser on fatigue perception ( $p < 0.001$ ) (Table 2).

**The Effect of Laser on Muscular Pain in Participants in Treatment and Placebo Groups.** The effect of laser on muscular pain- so-

called delayed onset muscle soreness (DOMS) - in participants of treatment and placebo groups was assessed by telephone interview 24 hours after the exercise session. Subjects were asked about their pain sensation by the VAS scoring scale to grade their muscular pain from 1(no pain) to 10 (maximum of tolerable pain).

Wilcoxon test was used to assess muscular pain in the 2<sup>nd</sup> session in both treatment and placebo groups. Results showed a significant difference between the two groups, meaning the laser effectively reduces muscle pain ( $p < 0.001$ ) (Table 2).



**Figure 1. Laser Irradiation Points of Participants**

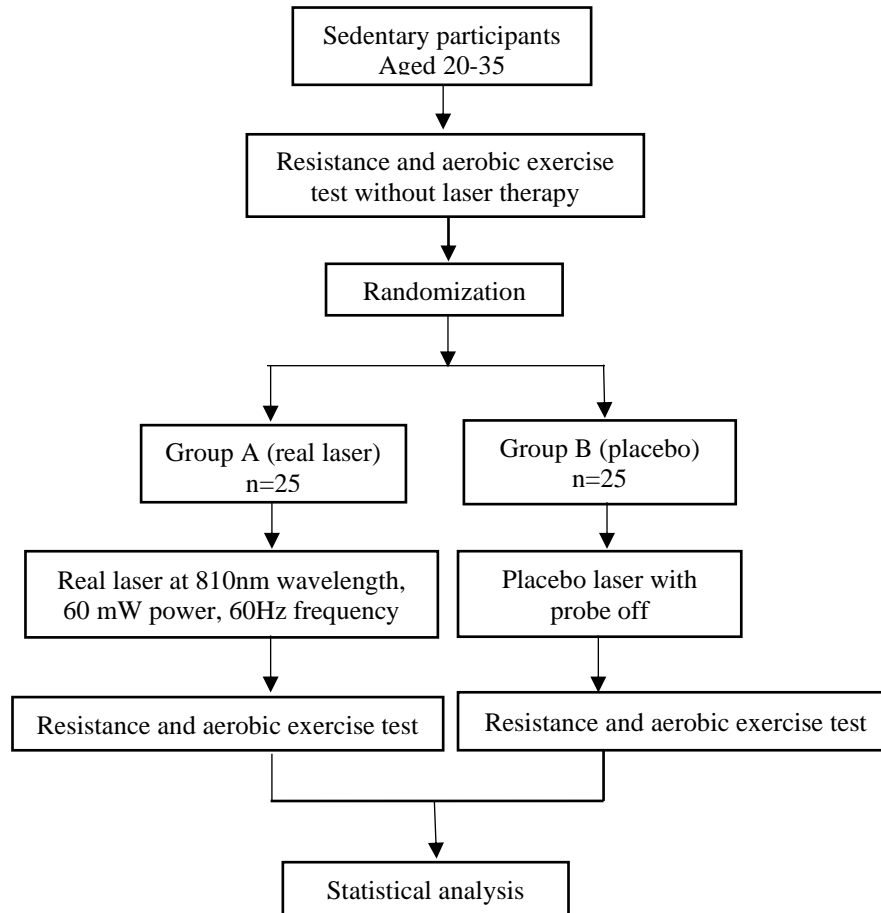


Figure 2. Flowchart of Study Design

## DISCUSSION

Laser therapy is a part of a therapeutic system called Photobiomodulation, which is a technique of soft tissue treatment by using the energy of light waves (25). According to the required effect, various wavelengths starting from red (630-660nm) to infrared (808-950nm) spectrums are used in this technique. The infrared spectrum is more absorbable and has more therapeutic effects.

In this study, the blood lactate level was measured as one of the muscular injury indexes. The placebo group's level of lactate in both sessions immediately and 1 hour after exercise showed a significant difference. This finding indicates that time is sufficient on the blood lactate level.

The placebo group's lactate level did not show any significant difference immediately and one hour after exercise in the 2<sup>nd</sup> session.

Lactate level showed a significant difference between the first and 2<sup>nd</sup> session immediately

after exercise in the treatment group. A significant difference was seen between lactate level 1 hour after exercise in the first and second sessions. These findings show that the laser is effective on the lactate level. In a study done by Ferrareddy et al. on one professional athlete, the laser's effect at 850nm on blood and urine CK, aerobic capacity (VO<sub>2</sub>), and blood lactate level as muscular fatigue markers were investigated. In this study, the laser was applied on the trunk and upper and lower limbs. They suggested using a laser before an exercise bout may decrease post-exercise blood lactate levels and improve renal and muscular performance (24). In a systematic review performed by Ferrareddy et al. on 46 RCTs, the authors demonstrated that the pre-exercise laser could reduce post-exercise lactate significantly (25).

In an investigation done in 2010 by Leal-junior et al., it was verified that using laser before exercise may decrease immediately post-exercise



blood lactate level, but the level of blood lactate 5, 10, 15, and 20 min after exercise did not show any significant differences between treatment and placebo groups (26).

In an investigation in 2017 done by Toma et al. by applying laser at 904nm on 18 female volunteers, it was suggested that pre-exercise laser might reduce fatigue but does not make any significant changes in lactate level (22).

In this study, the placebo group's number of weight repetitions did not show any significant changes between the first and second groups. In contrast, this number showed a significant difference in the treatment group between the first and second sessions. Also, the number of weight repetitions in the 2<sup>nd</sup> session of the placebo group and the treatment group showed a significant difference. These findings demonstrate laser to be effective in the improvement of muscular strength and endurance.

In a study in 2010 by Leal junior et al., it was proved that laser therapy before exercise could significantly increase elbow flexion times (26). In a study in 2014 by Felissimo et al. in 22 male athletes, the pre-exercise laser did not make any significant differences in improving strength (27).

Perceived fatigue, which was assessed subjectively, did not show a significant change between the first and second sessions in the placebo group, while in the treatment group, the difference was significant. Also, the perceived exertion in the 2<sup>nd</sup> session decreased significantly in the treatment group compared with the placebo group. This finding shows that laser therapy can reduce muscular fatigue.

In a study in 2015 by Ferraresi et al., a laser at 630 nm and 850nm wavelengths were applied on rats' lower limb. It was shown that a low-level laser could increase the mitochondrial content of muscles and delay exhaustion time. (28). In a systematic review in 2013 by Bursa et al. in 10 RCTs, they showed laser could delay the beginning of fatigue (29).

In a 2018 study by Manfrediny et al. on 20 male cyclists, pre-exercise laser-accelerated oxygen delivery to mitochondria, especially in type 2 fibers, caused an increase in maximal O<sub>2</sub> uptake, accelerated ATP synthesis, and delayed exhaustion time (30). However, in a study done by Alva et al. in 2014 on 18 sedentary subjects, it was shown that laser therapy before exercise test improves the immediate performance but has no effect on increasing time to exhaustion

(31). In a meta-analysis done in 2016 by Nampo et al. on 15 studies, the laser has not been effective in reducing DOMS in most studies. The authors suggested that laser therapy with a wavelength between 630-850 nm probably does not affect the management of musculoskeletal injuries (17).

Delayed onset muscle soreness, assessed subjectively 24 hours after the exercise session, in the placebo group did not show any significant differences between the first and second sessions. However, in the treatment group, the difference between the first and second sessions was significant. Also, in the second session, DOMS in the treatment group decreased significantly compared to the placebo group. These findings show that laser can decrease exercise-induced muscle injury.

In a study by Antonialy et al. in 2014 in 40 healthy non-athlete males, a laser at 905 nm, 670 nm, and 875nm reduced DOMS significantly (26, 32, 33). However, in a meta-analysis in 2016 on 15 RCTs, done by Nampo et al., in most studies, the appliance of laser could not have any effect on reducing DOMS (17).

Although these studies are performed in a wide range of wavelengths, therapeutic protocols, and different groups of participants and the results are very different, most of the authors suggest laser is useful in the improvement of athletic performance and musculoskeletal injury prevention, and the findings of this study are under this point of view.

## CONCLUSION

Supporting our hypothesis, we found that laser therapy at 810 nm wavelength and 60mw power before exercise training may improve muscular performance and reduce muscle soreness and fatigue. However, more studies are necessary for athlete participants, with more extended follow-up periods and more exercise sessions. Future studies should evaluate muscular and neural activity in response to laser therapy precisely by EMG and NCV tests. In the current study, our subjects were selected from the sedentary population. Therefore, generalizing the results to athletes requires further studies.

## APPLICABLE REMARKS

- low-level laser therapy may improve muscular strength and endurance and reduce fatigue and muscle soreness among young adults.

**CONFLICT OF INTEREST**

There was no Conflict of interest.

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