Exp. Theo. NANOTECHNOLOGY 10 (2026) 681-691 https://doi.org/10.56053/10.2.681

Rule of low-level laser therapy (910 nm) in treatment of rheumatoid arthritis: A comparative study between acute and chronic arthritis

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Received 21/1/2026, *Received in revised form* 24/3/2026, *Accepted* 3/4/2026, *Published* 15/4/2026

Rheumatoid arthritis (RA) is a systemic, autoimmune, inflammatory illness of unknown cause that mostly affects synovial joints and surrounding muscle. It causes significant disability and lowers quality of life. This study aims to assess the clinical impact of low-level laser therapy (LLLT 910nm) in acute and chronic phases of RA. In this study, it has been used diode laser 910nm wavelength to treat acute RA and chronic RA. Forty Wister male rats are divided into five experimental groups, with eight rats in each group: group I (Negative control), group II (Positive control acute RA), group III (Positive control chronic RA), group IV (Acute RA +LLLT 910nm), and group V (Chronic RA +LLLT 910nm). RF, IL-6, IL-1β, TNF-α, MDA, SOD is among the biochemical markers associated with rheumatoid arthritis that are evaluated and statistically examined for each group. While the levels of SOD considerably increased in groups IV and V compared to groups II and III, the levels of other biochemical markers (IL-6, IL-1 β, TNF-α, and MDA) significantly decreased ($p<0.05$). There is non-significant difference in MDA and SOD serum levels between LLLT 910nm treated groups (IV and V) as compared to each other ($P=0.236$ and $P=0.188$) respectively. LLLT 910nm effectively reduced inflammation in induced rat model for acute and chronic phases of RA.

Keywords: Low level laser therapy; Laser diode; Anti-inflammatory; Rheumatoid.

1. INTRODUCTION

Rheumatoid arthritis (RA) is an autoimmune disease that primarily affects the joints, causing inflammation, pain, swelling, stiffness, and progressive joint damage. Joints including the hands, wrists, ankles, and knees are among the joints that are more commonly impacted by this illness, which is referred to as a joint dysfunction [1]. People with RA develop persistent polyarticular synovitis as a result of their immune systems attacking healthy synovial joints. Excruciating pain, swelling, and fever

are finally brought on by this condition's degeneration of the articular cartilage, abnormalities in the joints, and bone destruction As the illness progresses, the patient's financial burden may increase and their general state of life may decline [2]. RA is a disease caused by immune dysregulation, one of the causes of immune dysregulation is the development of excessive autoantibodies. Examples of auto-antibodies found in RA include rheumatoid factor (RF [3]. The production of inflammatory cytokines, like IL-6, IL-17, IL-1β, and TNF-α by inflammatory cells activates osteoclasts and destroys bone [4]. Epidemiologic and genetic analyses, as well as clinical observations, suggest that RA pathogenesis can be divided into three distinct stages [5]. Stage 1 is the early RA where early symptoms may be modest and intermittent. Joint inflammation can occur, causing stiffness, discomfort, and swelling, particularly in the tiny joints of the hands and feet. Stage 2 is moderate RA where the symptoms grow more chronic and severe. Joint inflammation can spread to other joints, even larger ones like the knees, shoulders, and hips. Stage 3 is the severe RA chronic inflammation that causes severe joint damage and abnormalities. Joint function and motion are considerably reduced. Extraarticular symptoms, such as rheumatoid nodules and systemic problems, may develop. All of the pharmaceutical treatments for RA that are currently available have side effects, and long-term usage of these prescriptions can put patients in financial jeopardy. As life expectancy rises, more people are developing arthritis, underscoring the pressing need for effective, side-effect-free RA therapies [6]. A range of inflammatory illnesses have been treated in clinical settings using low-level laser therapy (LLLT) since 1981[7]. The photons of laser are anticipated to be absorbed by chromophores in cells, including the mitochondrial cytochrome c oxidase[8]. The primary source of cellular energy that restores normal cell function, lessens pain, and facilitates healing when cytochrome c oxidase activity is disrupted is adenosine triphosphate (ATP). Since reducing pain and inflammatory activity, preventing tissue degradation, enhancing function, and enhancing quality of life are the main objectives of treatment, LLLT has been utilized to treat RA. It works by absorbing red and infrared light through chromophores, which can intensify analgesic effects by boosting cellular proliferation, adenosine triphosphate (ATP) generation, protein synthesis, and enzyme activity [9]. LLLT is a non-invasive therapy A non-invasive treatment that reduce inflammation and encouraging tissue growth, it helps protect joints by managing arthritis-related cells [10]. Low intensity laser therapy's anti-inflammatory qualities theoretically support its ability to reduce symptoms related to arthritis [11]. Heat is not necessary for LLLT to function, as temperature variations during light irradiation are negligible [12]. Recently, there has been a lot of interest in creating a targeted medication delivery system with laser and nanotechnology since it can help increase the effectiveness of RA treatment [13]. Anti-rheumatic medications require high dosages and long-term, frequent use, which can result in severe side effects and poor patient compliance. Nanotechnology with targeting capabilities, sustained release, and other features has been proposed for RA treatment and has already shown promise in RA animal models in order to address the aforementioned issues and enhance therapeutic efficacy [14]. New developments in nanotechnology present an unparalleled chance to create a sophisticated combination treatment for RA. Initially, it enables the co-administration of several medications with improved physicochemical characteristics, targeted distribution, and controlled release profiles. Second, it makes the development of therapeutic nanomaterials possible, which allows combination regimens to incorporate multifunctional nanomedicines. Finally, it makes it easier to create whole nanoplatforms that combine several modalities, including imaging, phototherapy, and sonodynamic therapy [15]. Research on LLLT parameters is uneven, and the effectiveness of LLLT is still up for debate [16]. According to certain research, LLLT helps heal arthritis-related cartilage damage and reduce inflammation [17] Variations in LLLT's characteristics, including wavelength, power density, light dose, and treatment duration, can account for variations in its effectiveness [18]. This study aims to investigate the effects of LLLT at a wavelength of 910 nm on both acute and chronic stages of RA disease.

2. EXPERIMENTAL

2.1 Materials and methods

The diode laser used in this work has a wavelength of 910 nm, a power of 150 mW, and a spot size of 0.6 cm^2. In order to achieve the goal of the laser's anti-inflammatory effect on the acute and chronic phases of RA disease, the same conditions and number of sessions are used. In order to conduct this investigation, complete Freund's adjuvant (CFA) is induced in a rat model. In five polypropylene cages of eight rats each, forty male Wester rats weighing between 125 and 200 grams are housed at the Biotechnology Research Center of Al-Nahrain University in Baghdad. Iraq has a steady temperature of 20 to 25 degrees Celsius, a 12-hour light/dark cycle, and unfettered access to food and water. The Biomedical Engineering Department of Al-Nahrain University in Baghdad, Iraq, gave its ethics approval to the project. Two weeks are spent acclimating the animals before the trial began. Five experimental groups of eight rats each are randomly selected from among the rats (n=8): group I (negative control), group II (Positive control acute RA), group III (Positive control chronic RA), group IV (Acute RA +LLLT 910 nm), and group V (Chronic RA +LLLT 910 nm). Figure 1 shows the block diagram of the study.

In order to produce rheumatoid arthritis in the rat groups, 0.1 μL of Complete Freund's adjuvant (CFA), which is purchased from Sigma Chemical Company (St. Louis, MO, USA), is applied to each rat's right hind paw plantar area in groups II, III, IV, and V. Group IV (Acute RA +LLLT 910 nm) experienced acute inflammation and swelling following seven days of injection, whereas group V (Chronic RA +LLLT 910 nm) experienced chronic inflammation following three months of injection.

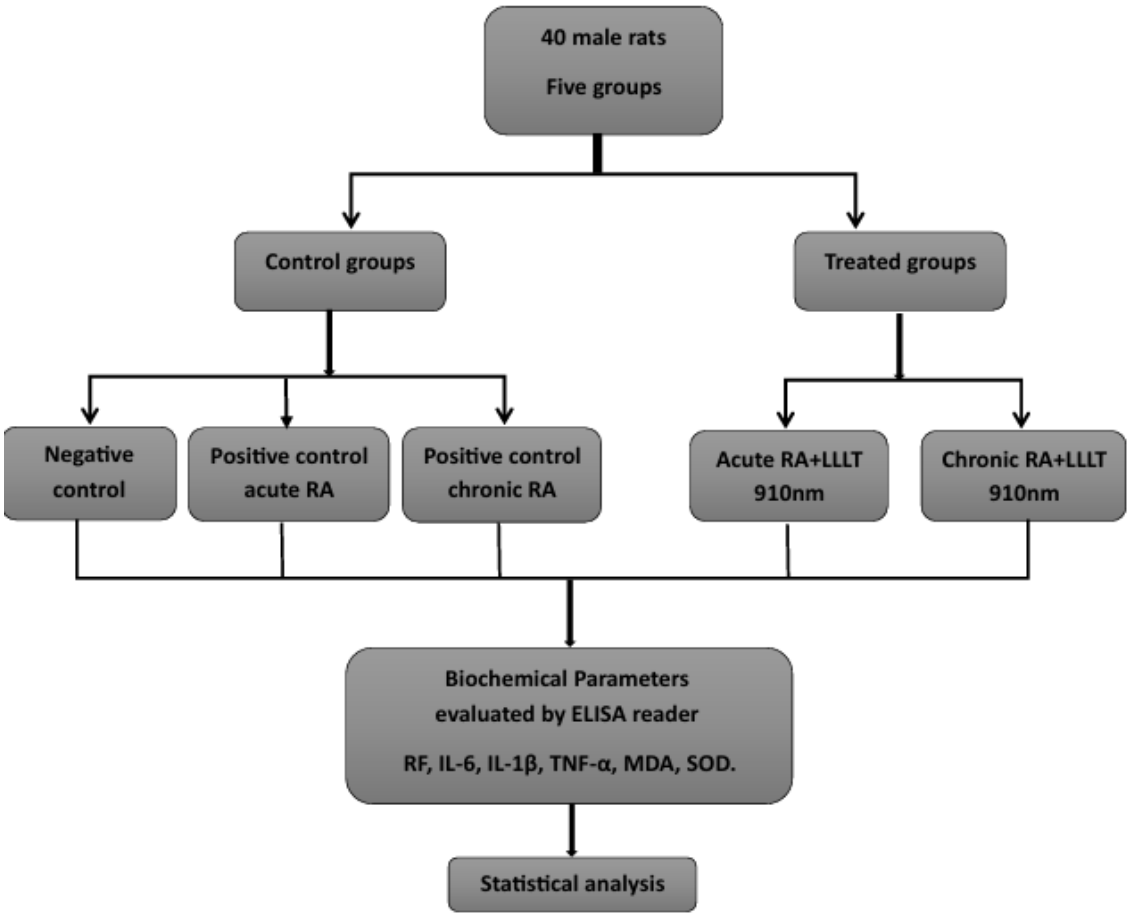

Figure 1 Block diagram of the study.

2.2 Low level laser therapy treatment protocol

One therapy protocol for the acute and chronic stages of RA disease used LLLT with a wavelength of 910 nm, power of 150 mW, energy of 2J, spot size of 0.6 cm^2, irradiation time of 120 s, and continuous mode. Group IV [Acute RA+LLLT 910nm] underwent LLLT one week following full Freund's adjuvant CFA induction, while group V [Chronic RA +LLLT 910nm] underwent LLLT three months later. Rats are placed on a table, and the laser is positioned 2 cm above the skin of the right paw of the LLLT groups. The LLLT operation is performed under general anesthesia using an intramuscular injection of a 10% ketamine solution and a 2% xylazine solution at a ratio of 2:1 (0.2 ml per 100 g). Twelve sessions, three sessions per week, made up the treatment. Every session used the same equipment, accessories, and laser settings, and took place at the same time of day.

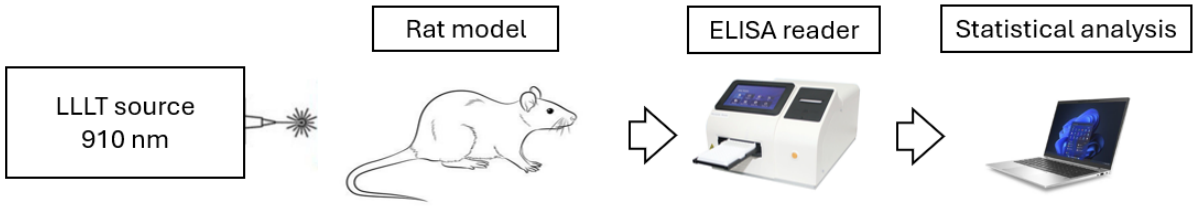

Figure 2 The low-level laser treatment system.

Deepening anesthesia, which is an overdose of an anesthetic mixture of xylazine and ketamine, is used to put all five rat groups to passing away 24 hours following the final treatment session. Rheumatoid factor (RF), interleukin-6 (IL-6), interleukin-1β (IL-1β), tumor necrosis factor-alpha (TNF-α), malondialdehyde (MDA), and superoxide-dismutase (SOD) are biochemical markers associated with RA that are assessed using blood serum. Using an ELISA reader, all of the abovementioned parameters are assessed as shown in Figure 3.

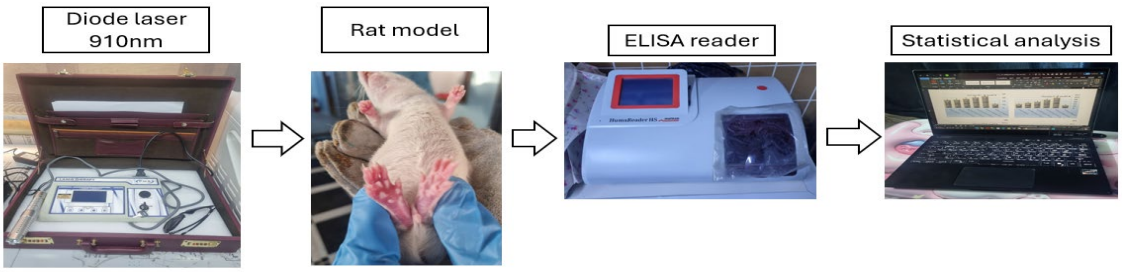

Figure 3 The experimental setup of the study.

2.3 Statistical analysis

The accessible statistical software program, IBM SPSS-29 (IBM Statistical Packages for Social Sciences, version 29, Chicago, IL, USA), is used to code, enter, present, and analyze the gathered data. The Paired-t-test for differences between two dependent means or paired observations is used to determine the significance of the mean differences (quantitative data). Statistical significance is determined by considering P values that are 0.05 or less. # the students-t-test at 0.05 level can be used to indicate a significant difference between two independent means, and [NS] represents a non-significant difference between two independent means using the students-t-test at 0.05 level.

3. RESULTS AND DISCUSSION

3.1 Results

After four weeks of treatment, the results for the groups treated with 910 nm LLLT (IV, V) are negative in four rats of eight with 50% negative RF, but the results for group I (negative control) are deemed negative for rheumatoid factor and positive for groups II and III, as shown in Table 1.

Table 1 The impact of LLLT 910 nm on RF in rats' model of Rheumatoid arthritis.

Groups / No. of rats	I Negative control	II Positive control acute RA	III Positive control chronic RA	IV Acute RA+LLLT 910 nm	V Chronic RA+LLLT 910 nm
1	0.164	0.346	0.412	0.386	0.295
2	0.159	0.401	0.396	0.299	0.291
3	0.204	0.366	0.456	0.314	0.411
4	0.144	0.298	0.391	0.322	0.325
5	0.139	0.334	0.441	0.125	0.152
6	0.15	0.451	0.471	0.186	0.16
7	0.209	0.418	0.508	0.17	0.186
8	0.147	0.422	0.514	0.217	0.166

Cut-Off value= 0.2408 RF negative RF positive

In the present study the mean serum levels of IL-6 for group I (Negative control) is (26.490±3.809 pg /ml), for group II (positive control acute RA) is (95.031±8.240 pg /ml), and for group III (positive control chronic RA) is (103.052±7.397 pg /ml). There is a highly significant difference in their means (P= 0.0001). The mean serum levels of IL-6 for group IV (acute RA +LLLT 910 nm), and group V (chronic RA +LLLT 910nm) are [(59.510±7.907 pg /ml), (47.531±6.348 pg /ml), respectively. There are highly significant decreased levels of serum IL-6 in groups (IV and V) when compared with that found in groups (II and III) (P=0.0001) as shown in Table 2 and Figure 4 (a).

Table 2 The impact of LLLT 910nm on IL-6 levels in rats' model of Rheumatoid Arthritis.

Groups	IL-6 (pg/ml)	P- value compared to			
	Mean ±SD	I	II	III	IV
I Negative control	26.490±3.809	-	-	-	-
II Positive control acute RA	95.031±8.240	0.0001#	-	-	-
III Positive control chronic RA	103.052±7.397	0.0001#	0.164[NS]	-	-
IV Acute RA +LLLT 910 nm	59.510±7.907	0.0001#	0.0001#	0.0001#	-
V Chronic RA +LLLT 910 nm	47.531±6.348	0.0001#	0.0001#	0.0001#	0.012#

The mean serum levels of IL-1β for group I (Negative control) is (27.115±4.255 pg /ml), for group II (positive control acute RA) is (67.635±4.476 pg/ml), and for group III (positive control chronic RA) is (76.229±4.519 pg/ml). There is highly significant difference in their means (P= 0.0001). The mean serum levels of IL-1β for group IV (acute RA +LLLT 910 nm), and group V (chronic RA +LLLT 910 nm) are [(53.208±7.533 pg/ml), (40.000±4.308 pg/ml), respectively. There are highly significant

decreased levels of serum IL-1β in groups (IV and V) when compared with that found in groups (II and III) (P=0.0001) as shown in Table 3 and Figure 4 (b).

Table 3 The impact of LLLT 910 nm on IL-1β levels in rats' model of Rheumatoid arthritis.

Groups	IL-1 β (pg/ml)	P- value compared to			
	Mean ±SD	I	II	III	IV
I Negative control	27.115±4.255	-	-	-	-
II Positive control acute RA	67.635±4.476	0.0001#	-	-	-
III Positive control chronic RA	76.229±4.519	0.0001#	0.017#	-	-
IV Acute RA +LLLT 910 nm	53.208±7.533	0.0001#	0.0001#	0.0001#	-
V Chronic RA +LLLT 910 nm	40.000±4.308	0.0001#	0.0001#	0.0001#	0.0001#

The mean serum levels of TNF- α for group I (Negative control) is (35.015±3.995 pg/ml), for group II (positive control acute RA) is (94.059±8.419 pg/ml), and for group III (positive control chronic RA) is (102.809±7.816 pg/ml). There is highly significant difference in their means (P= 0.0001). The mean serum levels of TNF- α for group IV (acute RA +LLLT 910nm), and group V (chronic RA +LLLT 910 nm) are [(63.397±8.987 pg/ml), (44.985±4.512 pg /ml)], respectively. There are highly significant decreased levels of serum TNF- α in groups (IV and V) when compared with that found in groups (II and III) (P=0.0001) as shown in Table 4 and Figure 4 (c).

Table 4 The impact of LLLT 910 nm on TNF- α levels in rats' model of Rheumatoid arthritis.

Groups	TNF- α (pg/ml)	P- value compared to			
	Mean ±SD	I	II	III	IV
I Negative control	35.015±3.995	-	-	-	-
II Positive control acute RA	94.059±8.419	0.0001#	-	-	-
III Positive control chronic RA	102.809±7.816	0.0001#	0.119[NS]	-	-
IV Acute RA +LLLT 910 nm	63.397±8.987	0.0001#	0.0001#	0.0001#	-
V Chronic RA +LLLT 910 nm	44.985±4.512	0.056[NS]	0.0001#	0.0001#	0.0001#

The mean serum levels of MDA for group I (Negative control) is (62.022±5.189 ng/ml), for group II (positive control acute RA) is (94.304±6.609 ng/ml), and for group III (positive control chronic RA) is (103.761±9.184 ng/ml). There is a highly significant difference in their means (P= 0.0001). The mean serum levels of MDA for group IV (acute RA +LLLT 910 nm), and group V (chronic RA +LLLT 910 nm) are [79.359±8.320 ng/ml), (87.033±6.213 ng/ml)], respectively. There are highly significant decreased levels of serum MDA in groups (IV and V) when compared with those found in groups (II and III) (P<0.05). There is a non-significant difference in MDA serum levels between groups (IV and V) as compared to each other (P=0.236) as shown in Table 5 and Figure 4 (d).

Table 5 The impact of LLLT 910 nm on MDA levels in rats' model of Rheumatoid arthritis.

Groups	MDA (ng/ml)	P- value compared to			
	Mean ±SD	I	II	III	IV
I Negative control	62.022±5.189	-	-	-	-
II Positive control acute RA	94.304±6.609	0.0001#	-	-	-
III Positive control chronic RA	103.761±9.184	0.0001#	0.091[NS]	-	-
IV Acute RA +LLLT 910 nm	79.359±8.320	0.0001#	0.002#	0.0001#	-
V Chronic RA +LLLT 910 nm	87.033±6.213	0.0001#	0.286[NS]	0.0001#	0.236[NS]

The mean serum levels of SOD for group I (Negative control) is (1981.500±202.522 pg/ml), for group II (positive control acute RA) is (1078.583±151.232 pg/ml), and for group III (positive control chronic RA) is (931.917±171.144 pg/ml). There is a highly significant difference in their means (P= 0.0001). The mean serum levels of SOD for group IV (Acute RA +LLLT 910nm), and group V (Chronic RA +LLLT 910 nm) are [(1647.333±187.667 pg/ml), (1454.417±140.056 pg/ml), respectively. There are highly significant decreased levels of serum SOD in groups (IV and V) when compared with that found in groups (II and III) (P<0.05). There is non-significant difference in SOD serum levels between groups (IV and V) as compared to each other (P=0.188) as shown in Table 6 and Figure 4 (e).

Table 6 The impact of LLLT 910 nm on SOD levels in rats' model of Rheumatoid arthritis.

Groups	**SOD (pg/ml)**	**P- value compared to**			
	Mean ±SD	**I**	**II**	**III**	**IV**
I Negative control	1981.500±202.522	-	-	-	-
II Positive control acute RA	1078.583±151.232	0.0001#	-	-	-
III Positive control chronic RA	931.917±171.144	0.0001#	0.444[NS]	-	-
IV Acute RA +LLLT 910 nm	1647.333±187.667	0.004#	0.0001#	0.002#	-
V Chronic RA +LLLT 910 nm	1454.417±140.056	0.783[NS]	0.001#	0.0001#	0.188[NS]

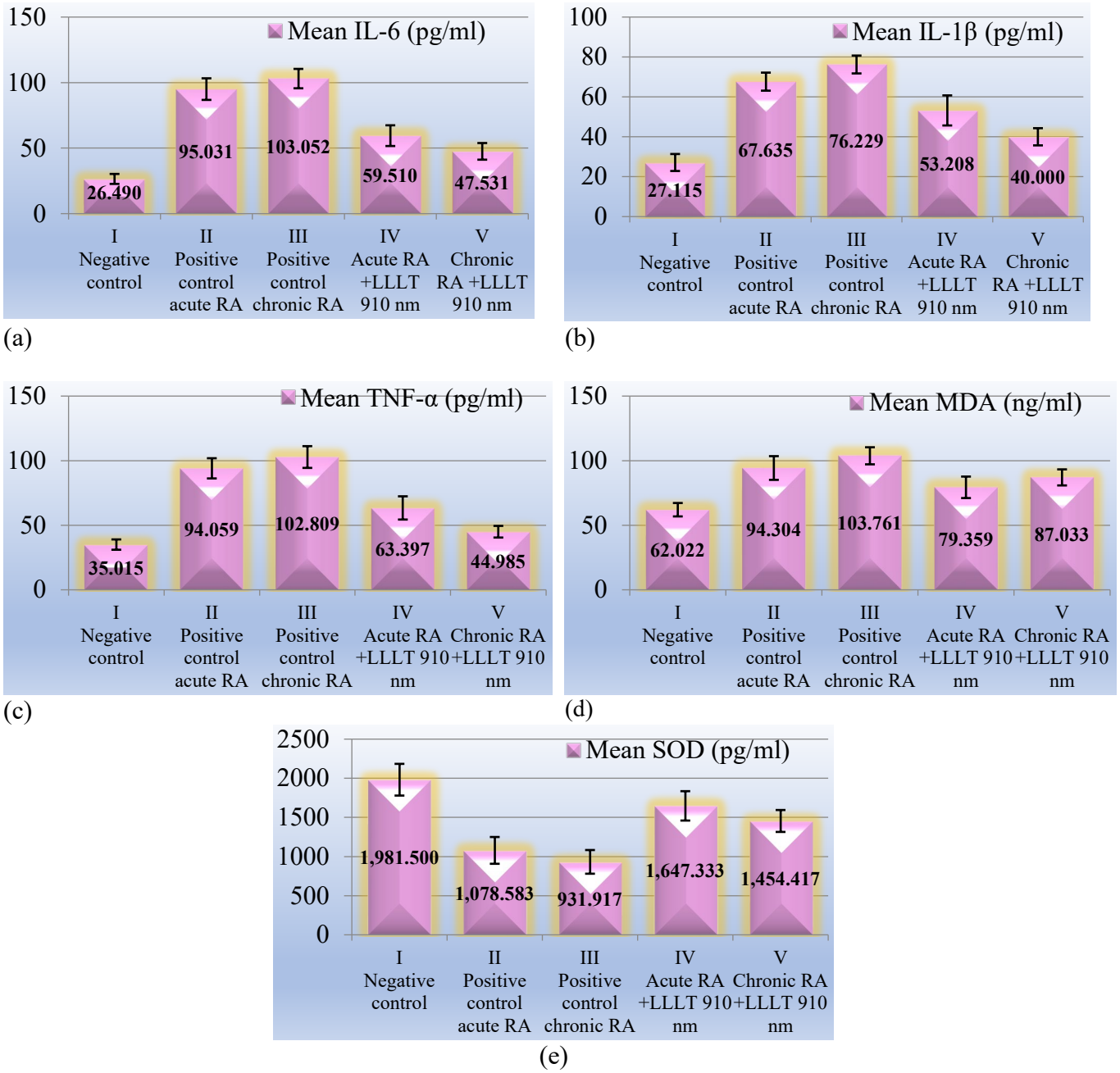

Figure 4 The difference in the mean of (a) IL-6, (b) IL-1β, (c) TNF-α, (d) MDA and (e) SOD between groups under the study.

Rheumatoid arthritis is among the most prevalent types of inflammatory arthritis. It is a degenerative inflammatory illness that is unique to joints and worsens with time. CFA-induced arthritis is a common experimental model of RA in rats that results in pathological RA that histologically resembles human arthritis. Rheumatoid arthritis treatment with continuous mode diode laser (wavelength 910nm, power 150mW, energy 2J, spot size 0.6 cm², and irradiation time 120 sec) reduced RA anti-inflammatory biochemical parameters. Diode laser with 910nm falls within the near infrared spectrum so LLLT at this wavelength had deeper penetration into the tissue due to longer wavelength. Deeper penetration gives higher therapeutic effect due to more laser photons interactions with cell mitochondria and eventually enhance biochemical parameters related to RA [19]. The results of biochemical parameters related RA due to using LLLT at 910nm wavelength are significant in decreasing serum levels of (IL-6, IL-1β, TNF-α and MDA) ($P<0.05$) and significant in increasing serum level of SOD ($P<0.05$) at

both acute and chronic phases of RA. The result has shown that this wavelength decreased the level of cytokines which are IL-and 6, IL-1β, TNF-α and reduced oxidative stress measured by MDA and increased antioxidant level measured by SOD which is indication that using this wavelength gives good anti-inflammatory effect. Due to the lack of clarity surrounding the appropriate therapeutic parameters of lasers, including wavelength, energy dosage, and treatment duration, numerous research studies about the clinical performance and treatment success of LLLT in RA produced inconsistent and controversial results Similar findings are reported by S. Okur and Z. Okumuş [20] using wavelength 905 nm, the treated groups showed successful LLLT-induced reduction of inflammation, mononuclear cell infiltration of the synovial membrane, and minimal cartilage erosion, chondrocyte degradation, and fibrillation Another study done by D. Pires et al [21] investigated if LLLT could reduce mRNA expression for TNF-α, IL-1β, IL-6, TGF-β cytokines, and COX-2 enzyme. Real-time PCR is used to assess the mRNA expression seven and fourteen days after tendinitis. LLLT irradiation at a wavelength of 780 nm required for 75 s at a dose of 7.7 J/cm^2 is given at different times: 12 hours and 7 days after tendinitis. It is discovered that LLLT reduced the expression of IL-6, COX-2, and TGF-β following tendinitis, respectively, in both acute and chronic phases when compared to tendinitis groups. The LLLT only decreased TNF-α expression during the chronic phase, but it had no effect on IL-1β expression at any point in time. They come to the conclusion that LLLT used in this manner lowers the expression of pro-inflammatory mediator mRNA, one of the characteristics of tendinopathies. Also A. C. A. Alves et al [22] assessed the histological characteristics of LLLT effects in various stages of RA progression in the knee and examined whether LLLT can control early and late stages of RA using a collagen-induced RA model. One LLLT (780 nm continuous mode) procedure is carried out daily starting 12 hours after collagen-induced RA, and a group receiving the identical LLLT parameters is treated starting 7 days following RA induction. We found that LLLT significantly reduced mononuclear inflammatory cells, exudate protein, medullary hemorrhage, hyperemia, necrosis, distribution of fibrocartilage, and chondroblasts and osteoblasts in both early and late stages of RA progression ($p<0.05$) when compared to the RA group. Based on these findings, we conclude that LLLT can control the inflammatory response in both early and late stages of RA progression. Similarly J. P. M. Issa et al [23] In a model of acute and chronic inflammation, the clinical and histological effects of low-intensity laser therapy (LILT) at 660, 808, or 905 nm as an alternative treatment are assessed. LILT has the potential to improve clinical symptoms [24]. They conclude that the LILT wavelength selection is contingent upon the kind of arthritis and can demonstrate reduced resorption area in this model as well as anti-inflammatory effects for chronic arthritis. For acute arthritis, the 905 nm laser typically exhibits the best anti-inflammatory effects, but the 660 nm laser demonstrated the best outcomes for chronic arthritis [25].

Laser fluence, which depends on the wavelength, output power, mode, irradiation time, and power density, is one of the most important factors to determine the relationship between the laser and tissue. Verifying the correlation between laser wavelength and rheumatoid arthritis type in rats with acute and chronic CFA-induced arthritic conditions is the main obstacle to this study. Ultimately, our findings showed that LLLT 910nm may successfully regulate inflammation in the CFA rat model by modifying the blood levels of RF, IL-6, IL-1β, TNF-alpha, SOD, and MDA [26-31].

4. CONCLUSIONS

The findings of this study show that LLLT 910 nm decreases inflammatory symptoms in a rat model of RA, both during the acute and chronic stages of the disease, according to statistical analysis of clinical observations. However, it is unknown whether the same effects occur for other fluences or modes when the same or different laser dosages are administered, therefore more research is needed.

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