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Effects of Low-Level Laser Therapy and Eccentric Exercises in the Treatment of Recreational Athletes With Chronic Achilles Tendinopathy

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Background: Eccentric exercises (EEs) are recommended for the treatment of Achilles tendinopathy, but the clinical effect from EE has a slow onset.

Hypothesis: The addition of low-level laser therapy (LLLT) to EE may cause more rapid clinical improvement.

Study Design: Randomized controlled trial; Level of evidence, 1.

Methods: A total of 52 recreational athletes with chronic Achilles tendinopathy symptoms were randomized to groups receiving either EE + LLLT or EE + placebo LLLT over 8 weeks in a blinded manner. Low-level laser therapy (λ = 820 nm) was administered in 12 sessions by irradiating 6 points along the Achilles tendon with a power density of 60 mW/cm^2 and a total dose of 5.4 J per session.

Results: The results of the intention-to-treat analysis for the primary outcome, pain intensity during physical activity on the 100-mm visual analog scale, were significantly lower in the LLLT group than in the placebo LLLT group, with 53.6 mm versus 71.5 mm (P = .0003) at 4 weeks, 37.3 mm versus 62.8 mm (P = .0002) at 8 weeks, and 33.0 mm versus 53.0 mm (P = .007) at 12 weeks after randomization. Secondary outcomes of morning stiffness, active dorsiflexion, palpation tenderness, and crepitation showed the same pattern in favor of the LLLT group.

Conclusion: Low-level laser therapy, with the parameters used in this study, accelerates clinical recovery from chronic Achilles tendinopathy when added to an EE regimen. For the LLLT group, the results at 4 weeks were similar to the placebo LLLT group results after 12 weeks.

Keywords: Achilles tendon; tendinopathy; low-level laser therapy; muscle-stretching exercises

Tendinopathy is a common disorder of the musculoskeletal system with various pathological manifestations. In an acute stage, inflammation dominates, with increased neutrophil cell migration, peritendinous edema, local tenderness, and stiffness.[33] In subacute and chronic cases, inflammation seems to play a minor role, and complex pathophysiological manifestations such as structural degeneration of the collagen matrix, partial rupture, intratendinous neovascularization,[32] increased local concentrations of neuropeptides,[2] and increased cell apoptosis[25,31] have been observed. It is well established that degeneration of the tendon matrix with loss of collagen fiber structure is found in chronic tendinopathies.[20,34]

Eccentric exercises (EEs) have been tested in a number of randomized controlled trials,[21,28] and the positive results have made EE the dominant conservative therapy in

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chronic tendinopathies. The term "eccentric" for describing exercises is, in some countries, substituted with the word "plyometric." In this report, however, we will use the term "eccentric," which is the most commonly used term in international sports medicine. An EE intervention period may be frustrating for athletes, as it is fairly long (typically 8 to 12 weeks). Eccentric exercises often induce some transient discomfort and pain, particularly in the beginning of the exercise regimens. Adjunctive interventions that reduce exercise-induced pain or shorten the EE therapeutic period should be of significant value.

Low-level laser therapy (LLLT) is a treatment that has been around for 26 years in clinical practice[15] and may have the potential to fill a role in tendinopathy management. It is only recently that we have come to understand some of the dose-dependent mechanisms behind reported clinical successes with LLLT. A successful strategy of treatment for tendinopathy should probably include modulation of inflammation in the acute phase and/or increased regeneration of collagen fibers in chronic tendinopathies. Low-level laser therapy has the potential to modulate both the inflammatory and the regenerative processes. In a recent review, we combined the results from 24 laboratory trials and identified that LLLT has wavelength-dependent and dose-dependent anti-inflammatory actions.[7] The identified therapeutic window for the anti-inflammatory effect of LLLT was in the range of 2 to 10 J/cm^2 for 810- to 830-nm wavelengths in trials with small animals. In addition, the biostimulatory effects of LLLT have been shown to reduce cell apoptosis[9] and promote collagen fiber synthesis within a low-range therapeutic window of 0.4 to 4 J/cm^2.[26,38] Recent clinical LLLT guidelines have also pointed out that high power densities should be avoided in the treatment of superficially situated tendinopathies of the elbow and the Achilles tendon.[47]

In the current study, we decided to investigate if active LLLT applied to the painful Achilles nodulus during the first 8 weeks of an EE regimen[12,14] could reduce pain faster than placebo LLLT and EE in chronic Achilles tendinopathy.

MATERIALS AND METHODS

Inclusion Procedure

The patients were either self-referred or referred by their physician for treatment of their Achilles tendinopathy at our clinic during the years 2004 through 2006. After a short clinical examination and before enrollment, they were informed by written and oral information about the nature of the experiment. Eligible patients who agreed to participate of their free will signed a written informed consent. The study was approved by the local Medical Ethics Committee.

Potentially eligible patients had to fulfill all of the following 5 inclusion criteria: (1) unilateral painful activity-related symptoms from the Achilles region for at least 6 months; (2) pain located in the Achilles tendon, at a point 2 to 6 cm proximal to the insertion on the os calcaneus; (3) crepitation and tenderness during palpation; (4) a single local thickening of the tendon <4 cm in size, and structural degeneration of tendon fibers revealed by ultrasonography imaging; and (5) restricted range of motion with <10° active dorsiflexion measured with goniometry.[3]

Patients were excluded if they had received oral or injected corticosteroids within the last 26 weeks, had symptoms present for <6 months, or had systemic inflammatory arthritis or familial hypercholesterolemia.[8]

The Program of Eccentric Exercises

The EE regimen used for both groups was adapted according to the established protocol for EE in Achilles tendinopathy.[12,22]

A physical education teacher of the center, with specialization in the rehabilitation programs, instructed the subjects verbally on how to perform the EE. The instructions were given on an individual basis, and the EE regimen was performed at the center with supervision 4 times per week for 8 weeks.

The patients started to execute the exercises of the calf muscles with the load of their body weight. When exercises could be performed without pain, the load was increased by using a backpack with 4 kg of lead weights.

The patients were standing in front of wall bars and holding them while carrying all their body weight on the forefoot with the ankle joint in plantar flexion. Then the athletes lowered themselves with weightbearing on the affected limb only by dorsiflexing the ankle.

The exercises were performed with the knee straight to eccentrically load the gastrocnemius muscle and with the knee flexed to eccentrically load the soleus muscle. After full dorsiflexion was reached in the ankle, the athletes returned to the starting position with the help of their arms and the unaffected lower extremity.

The schedule for the athletes was to complete 12 sets of 12 repetitions with 1 minute of rest between the sets, 4 days per week for 8 weeks. Athletes started with 1 set of 5 repetitions on the first day of exercises and gradually progressed to 8 sets of 12 repetitions, aiming to complete 12 sets of 12 repetitions by the fourth week of treatment.

Patients were told to go ahead with the exercise even if they experienced mild pain (<50 mm on a 100-mm visual analog scale [VAS]). However, they were told to stop the exercise if the pain was disabling or lasted into the next day.

In addition to the EE regimen, all subjects executed static stretching of the gastrocnemius and soleus muscles. The stretching exercises were performed with the help of the same physical education teacher of the center. The athletes were standing on a step in front of wall bars and holding them while stretching the gastrocnemius muscle with the knee in extension until they felt a mild stretch and likewise with knee in 30° of flexion for the stretching of the soleus muscle. This position was held for 15 seconds each time and then relaxed. The stretching exercise was repeated 10 times at each treatment session, 5 times before and 5 times after EE, with a rest of 20 seconds between each repetition. Patient compliance with the EE regimen was monitored.

Laser Unit and Treatment Procedure

The low-level laser unit was emitting infrared laser light from a laser probe with Ga-Al-As diode with a wavelength of 820 nm (Biotherapy 2000, Omega Universal Technologies, London, United Kingdom). The laser parameters are provided in Table 1.

TABLE 1
Parameters for Low-Level Laser Treatment

Wavelength	820 nm
Optical output	30 mW
Irradiation area/spot size	0.5 cm^2
Power density on skin	60 mW/cm^2
Number of irradiation points	6
Energy per point in each session	0.9 J
Total energy per session	5.4 J
Total energy delivered in 12 sessions	64.8 J
Irradiation technique	In skin contact, 2 points 1 cm apart medially, 2 points 1 cm apart dorsally, and 2 points 1 cm apart laterally over painful area in Achilles tendon

The athlete was placed in a prone position on the treatment couch with hip and knee extended and the ankle in maximal extension. The therapist's role in the experiment was only to apply the laser treatment, and the therapist was not involved in the evaluation of patient outcomes. Before laser treatment was applied, the area of the Achilles tendon was cleaned with alcohol. Six points, 2 points placed 1 cm apart on each side of the painful nodulus in the Achilles tendon, were then irradiated.

To maintain participant blinding, both the laser unit and the placebo laser unit produced a sound and a visible red light displayed during treatment. The physical therapist gave scripted instructions to all subjects, which stated that they may feel something like warmth or any other sensation such as rubbing, tingling, or discomfort. For eye protection from the laser beam, all subjects wore protective darkened glasses. Both groups were treated under the same conditions, and the patients were treated singly to avoid any influence from other participants. All treatment interventions (LLLT and EE) were performed in our center. The same physiotherapist (M.S.) treated athletes in the LLLT and LLLT placebo groups and administered active LLLT or placebo LLLT according to their group allocation. This therapist had no other tasks in the experiment, and she was the only member of the research team who knew the group allocation before the code was broken after the analysis had been completed. This therapist was explicitly instructed not to communicate any information as to whether active or placebo laser was given, neither to the patients nor to other members of the research team. All patients received 2 treatments per week in each of the first 4 weeks and 1 treatment per week in each of the second 4 weeks.

Outcome Measures

Each athlete was evaluated at baseline and after 4 and 8 weeks of treatment and at follow-up 12 weeks after the randomization.

Outcome measurements were performed by a blinded observer (A.S.) who was unaware of group allocation.

The primary outcome was pain intensity during activity measured on a 100-mm VAS. Secondary outcomes included morning stiffness severity, measured on a 100-mm VAS; crepitation, measured on a 100-mm VAS; tenderness on a 40-mm VAS; and range of active ankle dorsiflexion in degrees, measured by goniometry.

TABLE 2
Patient Demographic Data

	Laser	Placebo	Statistical Significance[a]
Age (y)	30.1 ± 4.8	28.8 ± 4.8	N.S.
Symptom duration (mo)	10.4 ± 3.3	9.4 ± 2.7	N.S.
Body height (cm)	176.4 ± 9.8	177.4 ± 9.8	N.S.
Body weight (kg)	72.9 ± 10.3	71.4 ± 9.4	N.S.
Active ankle dorsiflexion (deg)	8.9 ± 2.3	9.4 ± 2.1	N.S.
Female gender	8	7	N.S.
Male gender	12	13	N.S.

[a]N.S., not significant.

Statistical Analysis

The data were analyzed blindly with statistical software (SPSS version 14.0, SPSS Science Inc, Chicago, Ill) to ensure that group allocation was not revealed until after the final statistical analysis. The significance level was set at .05, and descriptive statistics of group means, standard deviation, and distribution of data were performed. Analysis of covariance, which adjusts for group differences at baseline, was used to test if differences in outcome were statistically significant. Data from patients dropping out or withdrawing from the study were included in the statistical analysis on an intention-to-treat basis, with their last outcome value carried forward for the missing evaluation time points.

RESULTS

The 2 groups were comparable with regard to age, symptom duration, body height, and body weight. Demographic data for the patient groups are provided in Table 2.

All patients were recreational athletes attending various sporting activities 1 to 5 times (mean, 2.1) per week. Their respective main sporting activities are shown in Table 3.

A total of 52 patients entered the randomization procedure. Twelve patients, 6 in each group, withdrew for lack of effect after the 4-week evaluation. All the other 40 patients completed all 12 sessions of LLLT or placebo LLLT and had a compliance of 85% to 100% to the EE regimen. The flow of patients in the trial is summarized according to the CONSORT (Consolidated Standards of Reporting Trials) guidelines (http://www.consort-statement.org/) in Figure 1.

Primary Outcome

The results for the primary outcome, pain intensity during physical activity, were significantly better in the laser group than in the placebo laser group at all time points except baseline. For the laser group, the result at 4 weeks

TABLE 3
Main Sporting Activity of Patients by Treatment Group

Sport	Laser	Placebo
Volleyball	4	5
Soccer	7	5
Basketball	1	1
Tennis	2	2
Running	6	7

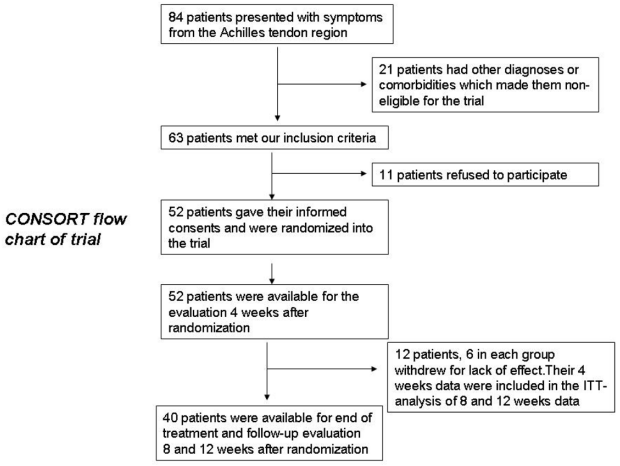

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flow chart. The figure shows the flow of patients in the different phases of the trial. Text boxes on the right-hand side summarize the exclusion of patients. ITT, intention to treat.

was similar to the placebo laser group result after 12 weeks. The results are summarized in Table 4 and Figure 2.

Secondary Outcomes

The secondary outcomes were significantly better ($P < .05$) in the laser group than in the placebo groups at 4, 8, and 12 weeks after randomization. The results are summarized in Figures 3 through 6.

Side Effects

Four of the patients reported minor or moderate aching pain in the calf after beginning the exercise regimen, but after adjustments of training load, the symptoms resolved, and no patients had to interrupt the exercise program because of this.

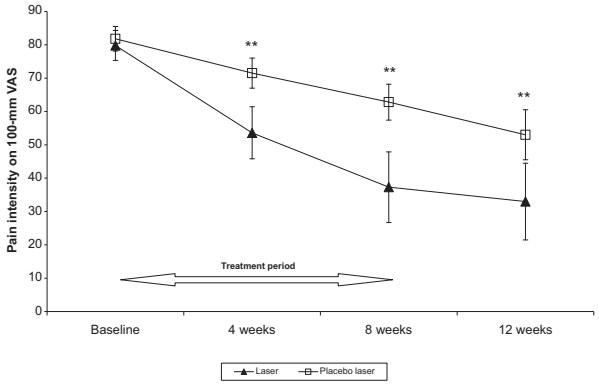

Figure 2. Pain intensity during physical activity. Pain intensity measured on a 100-mm visual analog scale (VAS) at baseline, 4 weeks, 8 weeks (end of laser and placebo laser treatments), and 12 weeks after randomization. The graphs show mean pain intensity of the laser group (black triangles) and the placebo laser group (white squares) and their respective 95% confidence intervals. $^{**}P < .001$.

DISCUSSION

For most athletes and sports medicine professionals, rapid recovery after injury is a prime concern. In chronic Achilles tendinopathy, surgical treatment results have often been poor,[27] and the good long-term results of the EE regimens introduced by Alfredson et al[4] were welcomed by athletes and specialists in the rehabilitation of sports injuries. The beneficial effects of EE regimens also persisted when subjected to rigorous scientific models like the randomized controlled trial designs.[28] But the rehabilitation period of approximately 3 months is fairly long, and parallel sports activity may also erase the positive effects of EE.[46]

Recent findings suggest that pharmacological treatment with nonsteroidal anti-inflammatory drugs impairs healing in acute tendon injuries[10,13]; glucocorticoid steroid injections also seem to give rapid pain relief but at the expense of delaying long-term recovery from lateral elbow tendinopathy.[41]

TABLE 4
Pain Intensity During Physical Activity Measured With Group Means at the Different Time Points and the Difference in Change of Means Between the Laser Group and the Placebo Laser Group

	Baseline	4 Weeks	8 Weeks	12 Weeks
Laser mean (SD)	79.8 (9.5)	53.6 (20.2)	37.3 (27.5)	33.0 (29.8)
Placebo laser mean (SD)	81.8 (11.6)	71.5 (11.6)	62.8 (14.2)	53.0 (19.5)
Mean difference	2.0	17.9[a]	33.6[a]	20.0[a]
Mean difference in change between groups (SD)		15.9 (18.5)[a]	24.8 (25.0)[a]	17.9 (26.6)[a]

[a] $P < .001$.

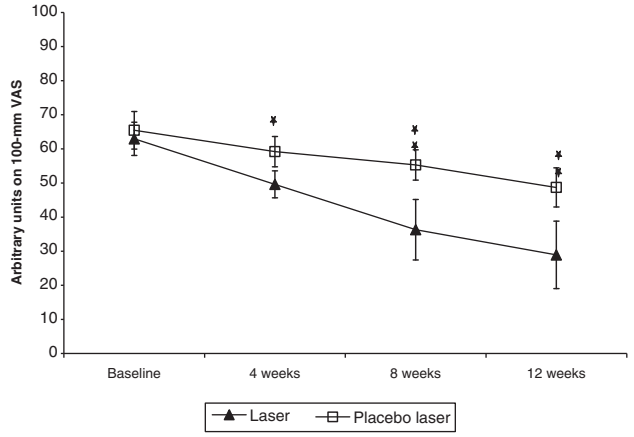

Figure 3. Crepitation severity during palpation. Crepitation severity measured on a 100-mm visual analog scale (VAS) at baseline, 4 weeks, 8 weeks (end of laser and placebo laser treatments), and 12 weeks after randomization. The graphs show mean crepitation severity of the laser group (black triangles) and the placebo laser group (white squares) and their respective 95% confidence intervals. *$P < .05$, **$P < .01$.

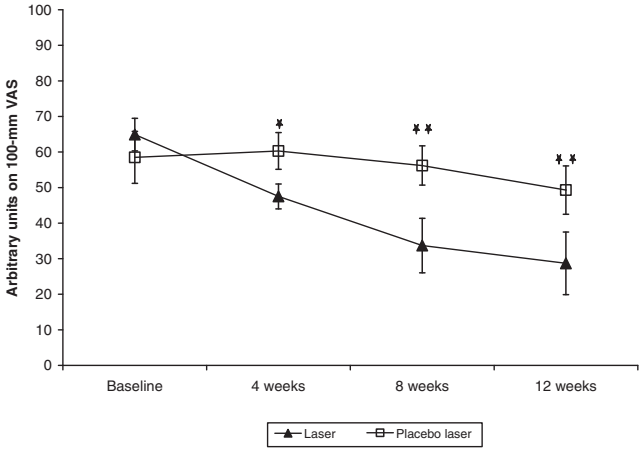

Figure 4. Morning stiffness severity. Morning stiffness severity measured on a 100-mm visual analog scale (VAS) at baseline, 4 weeks, 8 weeks (end of laser and placebo laser treatments), and 12 weeks after randomization. The graphs show mean morning stiffness of the laser group (black triangles) and the placebo laser group (white squares) and their respective 95% confidence intervals. *$P < .05$, **$P < .01$.

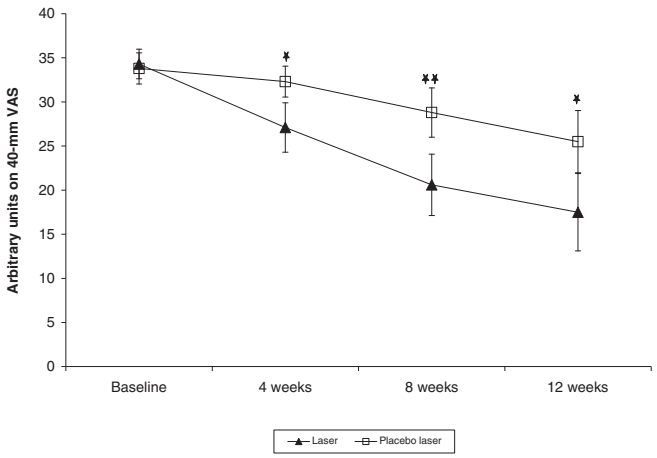

Figure 5. Tenderness during palpation. Tenderness measured on a 40-mm visual analog scale (VAS) at baseline, 4 weeks, 8 weeks (end of laser and placebo laser treatments), and 12 weeks after randomization. The graphs show mean tenderness of the laser group (black triangles) and the placebo laser group (white squares) and their respective 95% confidence intervals. *$P < .05$, **$P < .01$.

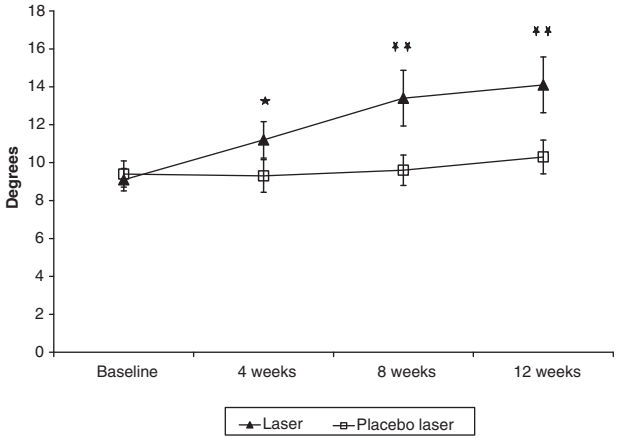

Figure 6. Active dorsiflexion. Degrees of active dorsiflexion at baseline, 4 weeks, 8 weeks (end of laser and placebo laser treatments), and 12 weeks after randomization. The graphs show mean active dorsiflexion of the laser group (black triangles) and the placebo laser group (white squares) and their respective 95% confidence intervals. *$P < .05$, **$P < .01$.

The purpose of the present investigation was 2-fold: first, to investigate the efficacy of low-level laser irradiation plus EE in recreational athletes with chronic Achilles tendinopathy during 8 weeks of treatment; and second, to determine whether benefits could be maintained for a period of 4 weeks after the end of treatment. Significant improvement in the LLLT group was observed in most measurement parameters and time points compared with the placebo LLLT group.

There are some limitations to our findings. We did not blind the therapist because we did not have a placebo probe available at the time of the study. However, we took precautionary actions such as the use of written information about treatment and explicit orders not to communicate with the trial observers to minimize this potential threat to trial validity. We could also have included validated outcome measures such as the fairly new Victorian Institute of Sports Assessment-Achilles (VISA-A) questionnaire.[39] At the time of the trial, however, the VISA-A questionnaire was not available in the native language of the participants. Nonetheless, 4 of the 8 questions in VISA-A are related to pain intensity during activity, which was our

main outcome measure. A fifth question in VISA-A is related to morning stiffness, which we also included in the evaluation. In addition, we included 3 clinical measures (crepitation, palpation tenderness, and active dorsiflexion), which in total should give a fairly valid picture of the clinical severity in Achilles tendinopathy.

Another limitation of our trial is the short time in follow-up measurements. However, our research question was to test if the onset of recovery is more rapid when LLLT is added in the first 8 weeks of a 12-week EE regimen, and we decided that follow-up 4 weeks after the end of LLLT probably would be sufficient to answer the research question. Although it has become more common to include a 1-year follow-up evaluation in tendinopathy trials, the value of this is often compromised by letting patients in placebo control groups cross over to active treatment,[19] lack of clinical and functional evaluations, and high drop-out rates.[37] In a 52-week perspective, more than 70% of the clinical improvement occurs in the first 12 weeks of EE regimens.[40] The most important motive for extending the follow-up duration beyond 4 weeks is governed by the recent discovery of a negative long-term effect from corticosteroid injection in lateral elbow tendinopathy.[41] This negative effect had been hidden by too-short observation periods in older lateral elbow tendinopathy trials. For LLLT, this is different, as long-term effects have already been examined by other authors. Positive short-term results in lateral elbow tendinopathy did not show signs of relapse after 6 months[45] or 12 months.[17] In other randomized placebo-controlled LLLT trials in knee osteoarthritis[16] and low back pain,[48] positive short-term effects do not seem to be threatened by relapses during the first 10 to 52 weeks after the end of LLLT. We admit that a longer follow-up would have been desirable in our study, but in view of the current LLLT and tendinopathy literature, it seems unlikely that we have missed vital LLLT effects in Achilles tendinopathy because of this shortcoming in our trial.

Low-level laser therapy is still surrounded by a myth of ineffectiveness and lack of support from scientific evidence.[35] Contrary to this myth, however, current literature shows that LLLT is one of the most extensively investigated therapies for tendinopathies, with more than 2 dozen randomized placebo-controlled LLLT trials being published.[6] Still, LLLT is hardly ever mentioned as a therapeutic alternative in reviews and clinical guidelines of tendinopathy treatments of the upper[44] or lower extremities.[1]

Low-level laser therapy has a potential to induce both a dose-dependent anti-inflammatory effect[7] and a dose-dependent stimulating effect on the connective tissue repair process.[11,38] However, results in clinical LLLT trials have been mixed, and there are probably at least 2 important explanations for that. One possible explanation was discovered by our research group when we found that the anti-inflammatory effect of LLLT was erased when we downregulated cortisol receptors with the cortisol antagonist mifepristone. Steroid injections also downregulate cortisol receptors and thereby the anti-inflammatory effect of LLLT, and several of the enrolled patients in LLLT trials in tendinopathies had already received unsuccessful steroid injections before enrollment.[18,36] The second explanation for poor results in clinical LLLT trials with superficially situated tendinopathies can be that the power density is too high for stimulating the fibroblast cells to increase production of collagen fibers. In the laboratory, LLLT with power densities >50 mW/cm^2 seem to inhibit fibroblast activity and collagen production.[26,29,43] Consequently, clinical guidelines from the World Association for Laser Therapy for LLLT in Achilles tendinopathy recommend that power density be below 100 mW/cm^2.[47] Nonsignificant effects of LLLT have been observed in clinical trials with power density >100 mW/cm^2 at anatomical locations such as the lateral elbow, where tendons are superficially located just below the subcutis layer of the skin.[5,23,36] However, results seem to be consistently positive for LLLT with lower power densities[6,24] and when LLLT is combined with an EE regimen.[42]

In Achilles tendinopathy, only a few randomized controlled LLLT trials have been published. Positive effects of LLLT have been observed in chronic cases of Achilles tendinopathy when a 904-nm wavelength was administered with fairly low power density (30 mW/cm^2) and low energy dose (1.5 J).[30]

The positive results of the current study seem to fit well with previous animal study findings of improved tendon fiber repair with LLLT[38] and the available clinical literature when the importance of optimal dosage is accounted for.

CONCLUSION

Low-level laser therapy with the parameters used in this trial seems to be a safe and effective method for more rapid recovery when combined with an EE regimen. However, it must be stressed that using power densities below 100 mW/cm^2 seems to be important for obtaining good results.

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