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Effects of Low-Level Laser and Plyometric Exercises in the Treatment of Lateral Epicondylitis

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ABSTRACT

Objective: **This study was undertaken to compare the effectiveness of a protocol of combination of laser with plyometric exercises and a protocol of placebo laser with the same program, in the treatment of tennis elbow.** ***Background Data:*** **The use of low-level laser has been recommended for the management of tennis elbow with contradictory results. Also, plyometric exercises was recommended for the treatment of the tendinopathy.** ***Methods:*** **Fifty patients who had tennis elbow participated in the study and were randomised into two groups. Group A ($n = 25$) was treated with a 904 Ga-As laser CW, frequency 50 Hz, intensity 40 mW and energy density 2.4 J/cm^2, plus plyometric exercises and group B ($n = 25$) that received placebo laser plus the same plyometric exercises. During eight weeks of treatment, the patients of the two groups received 12 sessions of laser or placebo, two sessions per week (weeks 1–4) and one session per week (weeks 5–8). Pain at rest, at palpation on the lateral epicondyle, during resisted wrist extension, middle finger test, and strength testing was evaluated using Visual Analogue Scales. Also it was evaluated the grip strength, the range of motion and weight test. Parameters were determined before the treatment, at the end of the eighth week course of treatment (week 8), and eighth (week 8) after the end of treatment.** ***Results:*** **Relative to the group B, the group A had (1) a significant decrease of pain at rest at the end of 8 weeks of the treatment ($p < 0.005$) and at the end of following up period ($p < 0.05$), (2) a significant decrease in pain at palpation and pain on isometric testing at 8 weeks of treatment ($p < 0.05$), and at 8 weeks follow-up ($p < 0.001$), (3) a significant decrease in pain during middle finger test at the end of 8 weeks of treatment ($p < 0.01$), and at the end of the follow-up period ($p < 0.05$), (4) a significant decrease of pain during grip strength testing at 8 weeks of treatment ($p < 0.05$), and at 8 weeks follow-up ($p < 0.001$), (5) a significant increase in the wrist range of motion at 8 weeks follow-up ($p < 0.01$), (6) an increase in grip strength at 8 weeks of treatment ($p < 0.05$) and at 8 weeks follow-up ($p < 0.01$), and (7) a significant increase in weight-test at 8 weeks of treatment ($p < 0.05$) and at 8 weeks follow-up ($p < 0.005$).** ***Conclusion:*** **The results suggested that the combination of laser with plyometric exercises was more effective treatment than placebo laser with the same plyometric exercises at the end of the treatment as well as at the follow-up. Future studies are needed to establish the relative and absolute effectiveness of the above protocol.**

INTRODUCTION

LATERAL EPICONDYLITIS (LE), commonly referred to as tennis elbow and/or lateral elbow tendinopathy, is one of the most common lesions of the arm.[1] Approximately 1–3% of the general population suffers from LE, with the dominant arm commonly affected.[2] This syndrom appears to be of longer duration and severity in women.[3] The prevalence of lateral epicondylitis is 30–60 years.[4,5] Recent studies confirm that the origin of the extensor carpi radialis brevis is the most commonly affected structure.[6] LE is a degenerative or failed healing tendon response, characterized by the increased presence of fibroblasts, vascular hyperplasia, increased amounts of proteoglycans and glycosaminoglycans, and disorganized collagen.[7,8] The main symptom of LE is sudden pain to the outer forearm over the facet of the lateral epicondyle. Many times the pain

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manifests gradually and worsens when the patient is trying to squeeze an object or to raise it, while the forearm is in pronation. In chronic situations, the pain is extended to all of the wrist extensors muscles and almost to the forearm.[9] These symptoms may affect activities of daily living.The diagnosis of LE can be confirmed by tests that reproduce the pain. These include palpation over the facet of the lateral epicondyle, resisted wrist extension, resisted middle finger extension, and passive wrist flexion.[10]

However, no ideal treatment has emerged for the management of LE, and up to 40 different therapeutic protocols have been proposed.[11–26] Low-level laser was used for the treatment of LE with contradictory results.[27–33] Also, there are rehabilitation programs that are proposed by experts that include stretching and strengthening the wrist extensors muscles.[34] Recent research points out that eccentric exercises can help in the prevention and rehabilitation of tendonitis.[35–37]

No study is known to us that investigates the effects of low-level laser and plyometric exercises in the treatment of LE. The aim of the present study was to investigate the effectiveness of a protocol that was constituted from laser and plyometric exercises in comparison to another protocol constituted only by plyometrics and placebo laser. The study was based on the hypothesis that the treatment of the patients who participated in the laser with plyometric exercises protocol (group A) would show better results in all measurement parameters, both after the end of the treatment, as well as after the 8-week follow-up period, an improvement that would not appear in the subjects of placebo laser and plyometric exercises (group B).

METHODS

Selection of subjects

The subjects selected for inclusion were women and men attending the Laboratory of Physical Therapy, Faculty of Human Movement and Quality of Life, where the study was performed. The period of inclusion was between January 2003 and June 2005. Patients were self referred or referred by their doctors or physiotherapists. The Panarkadikon Hospital Ethics Committee approved the study in January 2003.

Patients were included in the study only if they had diagnosed with LE for at least 5 weeks at the time of presentation. The diagnosis criteria included (i) pain manifestation during palpation of the lateral epicondyle, (ii) pain to the wrist extension by resistance, (iii) pain to the passive stretching of the wrist extensors muscles, and (iv) pain to the passive extension of middle-finger.[2,5] Patients who were not included in the study were ones who had some kind of treatment during the last month for their elbow pain, presented symptoms because of shoulder dysfunction or periarthitis, cervical or thoracic outlet syndrome, local or generalized polyarthitis or neuritis, and neurological symptoms that emanated from the radial nerve entrapment and bilateral epicondylalgia.[6]

This study was designed as a prospective, randomized, placebo-controlled and single-blinded study with an 8-week follow-up period. All patients received a written explanation of the trial before entering into the study and then gave signed consent to participate.

All patients were given instructions to use their arm during the study, but to avoid activities that caused irritation in the elbow. These activities included grasping, using a screwdriver, knitting, lifting, handwriting, driving a car, and shaking hands. Also, they were given advice to refrain from taking anti-inflammatory drugs throughout the study.

Sixty-two patients, who fulfilled the entry criteria, were admitted to the study, and they were randomly divided into two groups using numbered envelopes. Each group consisted of 31 patients. Twelve patients (seven from the experimental and five from the control) interrupted the therapeutic protocol, seeking other treatment methods because they had symptoms after six treatments. The study completed with 50 patients. Group A was constituted of 16 males and nine females, and group B was constituted of 15 males and 10 females.

Treatment protocols

The treatment was applied to affected arm. The class 3B Laser M 1000 (Level-Laser Co., Moglano Veneto-Milano, Italy) was used for the study. The laser parameters were as follows: The active medium of the laser was the Ga-As, the wavelength 904 nm, the mode continuous, the frequency 50 Hz, the power skin intensity 40 mW, the spot size 0.5 cm^2 the duty cycle 50%, the energy density 2.4 J/cm^2, and the duration of treatment per point 30 sec. The patient sat in a relaxed position with the elbow resting on the bed. Before laser treatment was applied, the area was cleaned with alcohol. Six areas over the facet of the lateral epicondyle, were irradiated.[38] In all cases, the laser set produced a sound and a red display. The physical therapist gave scripted instructions to all patients which stated that they were not to feel anything like warmth or any other sensation such as rubbing, tingling, or discomfort. During 8 weeks of treatment, the patients of the two groups received 12 sessions of laser or placebo. In the first 4 weeks, the subjects received two sessions per week (Monday and Friday) and, the next 4 weeks, one treatment per week (every Thursday). For protection from the laser beam, all subjects wore specific glasses. Both groups were treated under the same conditions and the patients were treated singly to avoid influencing one another. No complications were reported.

Plyometric exercises

The plyometric exercises regime used for both groups were adapted according to the guidelines by Stasinopoulos, el Hawary et al., and Kisner and Colby plyometric programs.[34,37,39] The maneuver was intended to be pain-free and no patient reported increased pain during plyometric exercises. It consisted of slow progressive plyometric exercises of the wrist extensors. Five sets of eight repetitions of slow progressive plyomeric exercises of the wrist extensors at each treatment session were performed, with one minute rest interval between each set.

Plyometric exercises of the wrist extensors were performed with the elbow on the branch of a chair in full extension, the forearm in pronation, the wrist in an extended position (as high as possible), and the hand hanging over the edge of the chair. From this position, patients flexed their wrist slowly while counting to 20, then returned to the starting position with the help of the other hand. Patients were told to continue with the exercise even if they experienced mild pain. However, they were told to stop the exercise if the pain became disabling. When patients were able to perform the eccentric exercises without experiencing any minor pain or discomfort, the load was increased using free weights. Patients of both groups, at the duration of daily activities used an elbow band (counterforce brace, Miller-751 LPS).

All subjects except the plyometrics, executed static stretching of the wrist extensors. The exercise was performed with the help of the physical educator teacher (PET) of the lab, who was a specialist in exercise rehabilitation of overuse injuries. The PET was masked to the treatment plan. The PET placed the elbow of the patient in full extension, the forearm in full pronation, and the wrist in flexion and ulnar deviation according to the patient's tolerance. This position was held for 15 sec each time and then relaxed. The stretching exercise repeated 10 times at each treatment session, five times before and five times after the plyometric exercises, with a rest of 20 sec between each repetition. Plyometric exercises and stretching was given two times a week for 16 weeks.[39]

Evaluations

A blinded physical therapist unaware of the treatment allocation performed the clinical assessments at baseline, at week 8, and at week 8 follow-up period. The evaluation consisted of measures of pain, grip strength, weight test and range of motion.

Pain. The patients assessed the intensity of pain at rest, at palpation over the facet of the lateral epicondyle, during resisted wrist extension, during middle finger test and during strength testing. As pain characterized a feeling of distress of the patient over the facet of the lateral epicondyle, that reproduced during the above maneuvers. The visual analog scale (VAS) consisted of a continuous horizontal line of 100 mm in length, with anchor points "no pain" and "worst pain." Immediately after the test, the patient was asked to use the VAS to rate the magnitude of pain felt. The distance from the extreme left on the VAS to the subject's mark was then measured to the nearest millimeter.[40,41] FiveVASs were used.

Wrist range of motion. The patient, with elbow extended and forearm pronated, flexed the wrist and, at the point that pain was felt, recorded the degree of motion.[39]

Grip strength. It was measured by using a smedley handheld dynamometer (Preston Corp., Clifton, NJ). The subject was standing with the elbow completely extended and the shoulder and the radicular joints in neutral rotation. The patient was instructed to slowly squeeze the dynamometer and stop at the first onset of discomfort. Three trials were performed, separated by a 20-sec time interval. Stratford et al. found that the best estimation of the patient' s grip strength was the average of all measurements.[42]

Weight-test. Patient's forearm was supported on a table with the shoulder in 60 degrees of flexion, elbow was fully extended, and forearm pronated. From this position, the patient lifted the hand in wrist extension, without pain, with weights of 1, 2, and 3 kg.

Statistical analysis

The SPSS (version 12.0 for Windows 2000) statistical package was used for the analysis of the data. After assessing the

Table 1. VAS Recordings[a]

	Pre-treatment	*Week 8*	*8-week follow-up*
Variables	*Mean ± SD (95% CI)*	*Mean ± SD (95% CI)*	*Mean ± SD (95% CI)*
Pain at rest			
Group A	6.95 ± 9.81 (2.81–11.10)	3.41 ± 6.26 (1.19–5.92)‡	1.61 ± 3.30 (0.35–2.97)†
Group B	6.10 ± 8.43 (2.56–9.68)	4.75 ± 7.63 (3.17–8.55)	2.93 ± 3.11 (0.82–5.01)
Pain at palpation			
Group A	64.79 ± 23.88 (54.70–74.01)	23.29 ± 19.51 (19.05–35.53)†	14.79 ± 14.61 (8.60–20.98)‡‡
Group B	58.28 ± 22.42 (50.73–69.67)	39.35 ± 15.07 (28.34–44.92)	28.20 ± 16.04 (19.27–38.13)
Pain on isometric testing			
Group A	52.50 ± 20.82 (43.70–64.29)	23.20 ± 14.18 (17.22–29.190)†	10.50 ± 9.59 (8.45–16.56)‡‡
Group B	47.08 ± 18.19 (39.39–54.76)	35.54 ± 16.98 (27.33–39.92)	26.62 ± 15.25 (18.25–39.67)
Pain during middle finger test			
Group A	49.25 ± 21.15 (40.31–58.18)	20.41 ± 12.11 (15.30–25.25)‡‡	13.63 ± 7.85 (10.17–18.44)†
Group B	53.02 ± 23.95 (42.88–63.11)	35.33 ± 17.44 (26.83–37.47)	27.05 ± 25.24 (19.57–40.72)
Pain during grip strength testing			
Group A	38.14 ± 18.46 (30.20–45.79)	19.79 ± 9.11 (13.95–24.63)†	6.21 ± 7.77 (5.15–12.37)‡‡
Group B	34.25 ± 16.04 (27.47–41.02)	25.07 ± 10.72 (17.87–29.20)	19.67 ± 9.28 (6.59–14.68)

[a]Pre, during 8 weeks of treatment, and at 8-week follow-up results of the VAS recordings (pain at rest, pain at palpation, pain on isometric testing, pain during middle finger test, and pain during grip strength testing) of groups A and B, and significance between them.

†$p < 0.05$; ††$p < 0.01$; ‡$p < 0.005$; ‡‡$p < 0.001$.

CI, confidence interval.

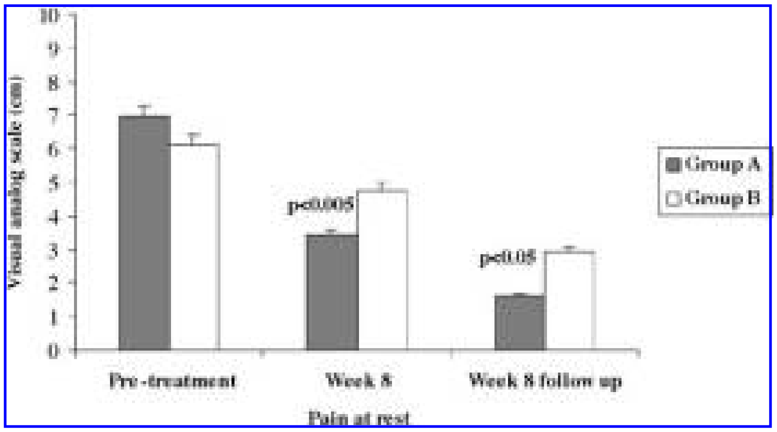

FIG. 1. Pre, during 8 weeks of treatment, and at 8-week follow-up results of the VAS recordings of pain at rest, between groups A and B, and the significance between them.

normal distribution of the data, a mixed 2 × 3 repeated-measures analysis of variance (ANOVA) model was used to analyze the data from each variable within groups (group A, group B), among treatment phases and follow up period and between groups (group A vs. group B), at pre-treatment, at the end of treatment (week 8) and at the end of follow up period (week 8). Multiple comparisons by Tukey post-hoc method and independent samples *t*-test were used to highlight the significant differences where needed. The probability level for significance was set at 0.05.[43] All parameters are expressed as mean ± standard deviation, with 95% confidence interval.

RESULTS

There were no differences before treatment between subjects in age (45.2 ± 2.86 vs. 46.1 ± 2.72 years), in body mass (75.4 ± 2.24 vs. 75.9 ± 2.14 kg) and in the duration of the symptoms (6.28 ± 2.7 vs. 6.20 ± 2.8 years).

Effects of laser on pain

There was a significantly greater decrease of pain at rest in the group A than in the group B at the end of 8 weeks of the treatment ($F = 6.51$, $p < 0.005$) and at the end of following up period ($F = 4.13$, $p < 0.05$). A pattern similar to that of overall pain was observed for pain at palpation and pain on isometric testing. The results showed that, relative to the group B, the group A had a significant decrease in pain at palpation and pain on isometric testing at 8 weeks of treatment ($F = 4.01$, $p < 0.05$), and at 8 weeks follow-up ($F = 10.27$, $p < 0.001$). Similarly, the differences in pain during middle finger test, between the group A and group B were statistically significant at the end of 8 weeks of treatment ($F = 5.89$, $p < 0.01$), and remained so at the end of the follow-up period ($F = 4.21$, $p < 0.05$). More, the pain during grip strength testing was significant decreased in group A in comparison with group B at 8 weeks of treatment ($F = 4.33$, $p < 0.05$), and at 8-week follow-up ($F = 9.66$, $p < 0.001$; Table 1, Figs. 1–5).

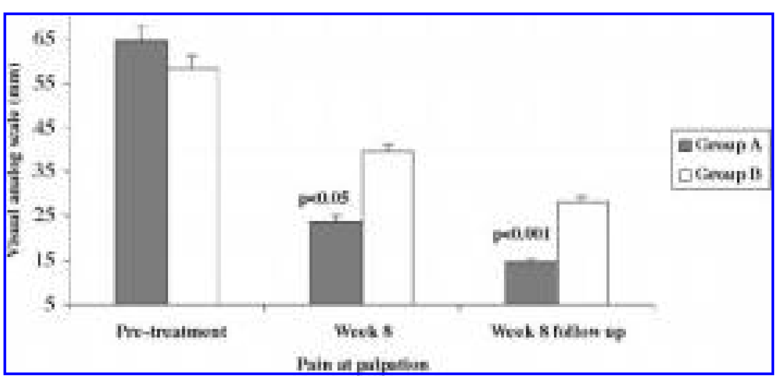

FIG. 2. Pre, during 8 weeks of treatment, and at 8-week follow-up results of the VAS recordings of pain at palpation between groups A and B, and the significance between them.

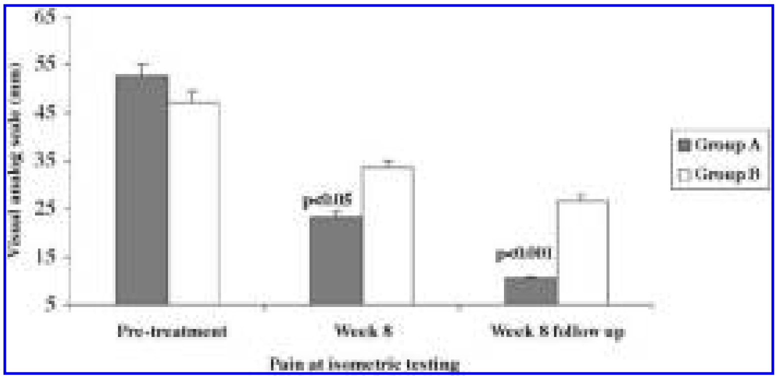

FIG. 3. Pre, during 8 weeks of treatment, and at 8-week follow up results of the VAS recordings of pain on isometric testing, between groups A and B, and the significance between them.

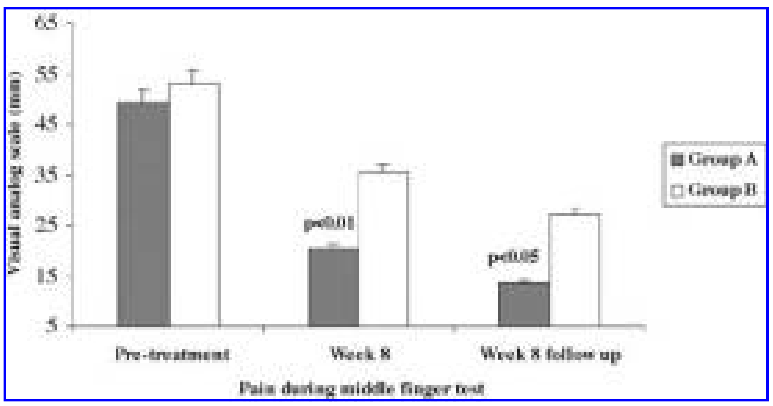

FIG. 4. Pre, during 8 weeks of treatment, and at 8-week follow-up results of the VAS recordings of pain during middle finger test between groups A and B, and the significance between them.

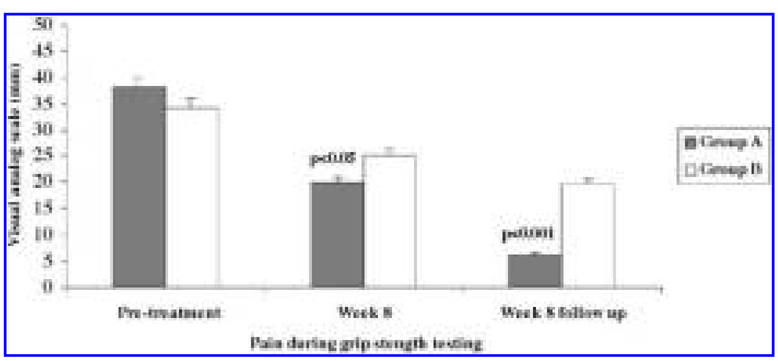

FIG. 5. Pre, during 8 weeks of treatment, and at 8-week follow-up results of the VAS recordings of pain during middle finger test between groups A and B, and the significance between them.

TABLE 2. RANGE OF MOTION, GRIP STRENGTH, AND FREE-WEIGHT ELEVATION

	Pre-treatment	Week 8	8-week follow-up
Variables	*Mean ± SD (95% CI)*	*Mean ± SD (95% CI)*	*Mean ± SD (95% CI)*
Range of motion (degrees)			
Group A	77.04 ± 10.53 (65.59–78.49)	82.81 ± 12.12 (66.91–82.66)	87.15 ± 12.73 (67.21–84.25)††
Group B	74.31 ± 9.72 (63.59–79.49)	76.57 ± 10.44 (65.29–80.11)	79.33 ± 11.07 (66.12–79.46)
Grip strength			
Group A	26.17 ± 8.78 (17.84–28.35)	33.37 ± 9.45 (19.11–30.67)†	40.22 ± 10.45 (27.32–38.74)††
Group B	23.68 ± 8.03 (16.41–29.72)	25.52 ± 8.37 (17.23–28.99)	29.31 ± 8.98 (21.04–33.27)
Freeweight elevation (Kg)			
Group A	1.14 ± 0.81 (0.83–1.49)	1.25 ± 0.94 (0.92–1.65)†	1.67 ± 1.37 (1.21–2.58)‡
Group B	1.10 ± 0.72 (0.79–1.45)	1.13 ± 0.77 (0.82–1.54)	1.26 ± 0.96 (0.91–1.59)

[a]Range of motion, grip strength, and free-weight elevation, before the treatment, at the end of 8 weeks of treatment, and at 8-week follow-up period of groups A and B, and significance between them.

†$p < 0.05$; ††$p < 0.01$; ‡$p < 0.005$; ‡‡$p < 0.001$.

CI, confidence interval.

Effects of laser on wrist range of motion, grip strength, and weight-test

The results showed that, relative to the group B, the group A had a significant increase in the wrist range of motion at 8-week follow-up ($F = 5.58$, $p < 0.01$). According to the grip strength, there was a statistical increase at 8 weeks of treatment ($F = 4.17$, $p < 0.05$) and at 8-week follow-up ($F = 5.14$, $p < 0.01$). Finally, relative to group B, the group A had a significant increase in weight-test that was improved at 8 weeks of treatment ($F = 4.16$, $p < 0.05$), and at 8-week follow-up ($F = 6.11$, $p < 0.005$; Table 2, Figs. 6–8).

DISCUSSION

We undertook this study to ascertain whether a combination of low-power laser treatment with plyometric exercises for eight weeks and a eight week follow up period for patients with lateral epicondylitis would indicate any effects on functional activities of the arm. The parameters we followed were pain at rest, pain at palpation, pain on isometric testing, pain during middle finger test, range of motion, grip strength and the free weight test. After eight weeks of the treatment all the above parameters showed significant inprovement in comparison with placebo laser with plyometric exercises group. In addition, at the end of the eight weeks follow up period, all of these parameters remained relatively inproved among members of the laser group, who did plyometric exercises.

Low-level laser therapy causes photobiological biostimulation. Studies *in vitro* and *in vivo* have produced contradictory results. Some researchers have demonstrated clear effects, others not.[44–49] Whilst much work has been carried out to study the effects of laser light on wound healing,[50] there is doubt that enough laser energy will pass through the skin to affect underlying tissues.

Experts in the field indicate that, depending on the particular light delivery system coupled to an irradiation source, the action of light in biological systems depends at least on three threshold parameters: wavelength, energy density and intensity.[51]

In this study we choose a GaAs laser, wavelength of 904, intensity 40 mW and an energy density of a dose of 2.4 J/cm^2. The latter was in accordance with the energy density range

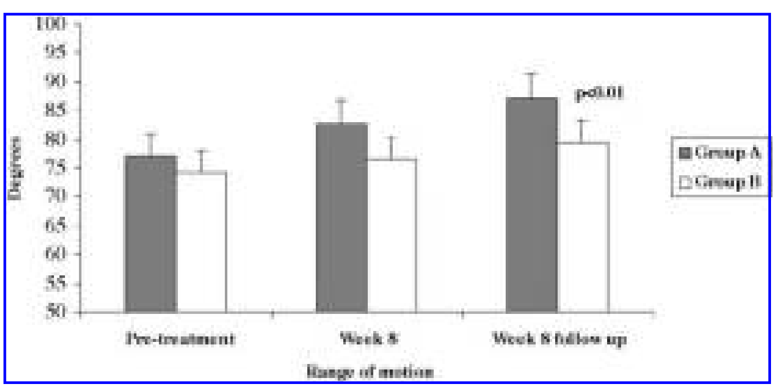

FIG. 6. Pre, during 8 weeks of treatment, and at 8-week follow-up results of the range of motion recordings between groups A and B, and the significance between them.

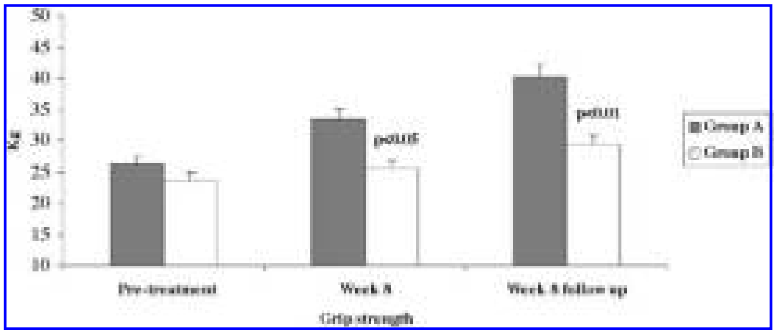

FIG. 7. Pre, during 8 weeks of treatment, and at 8-week follow-up results of the grip strength recordings between groups A and B, and the significance between them.

described in the basic Arndt-Schultz-curve.[52] There is an evidence that cells reacts different at different energy density levels.When the levels were too small, there were no observable effects. Higher levels resulted in the inhibition of cellular functions.[52] The present results suggest that active laser with the above parameters might have allowed energy to penetrate to subcutaneous tissues in spite of absorption by the skin. The incident energy density used in the study was the energy density suggested for the treatment of superificial bone-tendon junctions as in the case of LE.[38,52]

In general, studies that used similar laser apparatus and parameters with the present study, to test the efficacy of laser light in the patients suffering from LE showed positive results. Gudmundsen and Vinke,[53] investigated the effects of a 904 nm Ga-As laser with energy density 2.4 J/cm^2 /point in patients suffering from LE and found that the subjects who had received active laser treatment improved in all measurement parameters. Similar results reported by Vasseljen et al,[28] who investigated the effects of a 904 nm Ga-As level laser in patients with LE.

Hartvig et al.,[54]compared two laser: He-Ne and infrared in patients with LE and observed after one month significant improvement in al symptoms. Haker and Lundeberg [27] in an other study investigated the effects of laser an Ga-As (904 nm) with a power 12 mW, frequency 70 Hz in patients with LE and found that the subjects that received laser treatment had significant improvement. Simunovic et al,[45] investigated the effects of laser in 274 patients with LE. The laser devices used was a GaAlAs 830 nm CW and a He-Ne 632.8 nm combined with Ga-As 904 nm. The results showed a total relief of the pain with consequent improved functional ability that was achieved in 82% of acute and 66% of chronic cases.

On the contrary Haker et al.,[29] applied Laser He-Ne (632.8 nm) and Ga-As (904 nm) to patients with LE and showed that the two types of laser had no beneficial effects. Similarly, Lundeberg et al,[30] in an other study applied laser Ga-As, 904 nm in acupuncture points LI 10,11,12,Lu 5 and SJ 5 in patients with LE, and there were no differences in the measurement parameters between groups. Haker and Lundeberg[31] investigated the effects of laser GaAs (904 nm) and He-Ne (632.8 nm) in pain intensity in patients with lateral epicondylitis. They found no significant differences after 10 sessions. Similar negative results had those that were published by Vasseljen.[32] He investi-

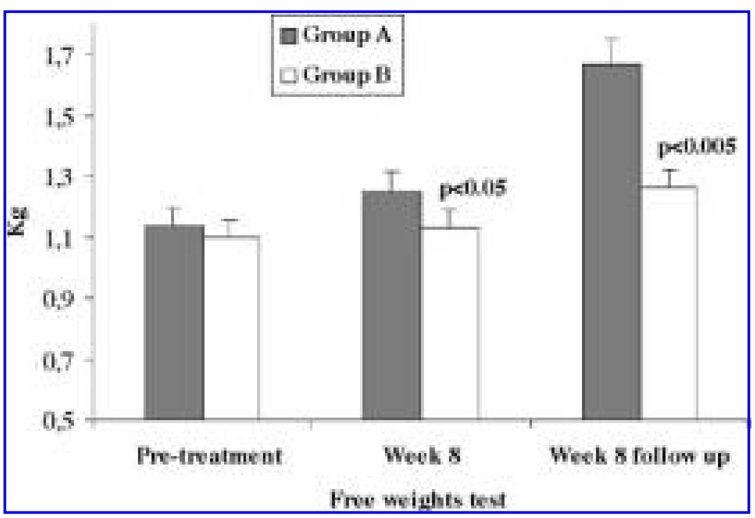

FIG. 8. Pre, during 8 weeks of treatment, and at 8-week follow-up results of the free weights elevation between groups A and B, and the significance between them.

gated the effects of ultrasound and laser Ga-As (904 nm) in patients with LE and measured range of motion, pain, grip strength and weight test before the treatment and after 10 sessions. The negative results were mainly due to different lasers being used and differences in the treatment parameters. We hypothesized that the patients with LE, would be show better results in all measurement parameters, if simultaneously with laser treatment participated in plyometric exercises and stretching two times a week.

Plyometric exercises offer adequate rehabilitation for tendon disorders, but many patients with tendinopathies do not respond to this prescription alone.[56] The load of plyometric exercises was increased according to the patients' symptoms because the opposite has shown poor effects.[57] Plyometric exercises were performed at a low speed in the treatment sessions because this manuever allows collagen to heal.[58] Plyometrics reduces the pain intensity and improve function of the wrist extensor muscles. The way that an plyometrics achieves the goals remains uncertain.[59,60] It is believed that because of inflammation, free nerve endings of the area are irritated and produce pain, that does not allow the patient to use the elbow in concrete motions. Plyometrics can improve local inflammation, realign the collagen fibers near to insertions in the periosteum.

Following completion of the study, this protocol was offered to all of the patients. All accepted and all improved. Twelve treatments were sufficient to elicit a significant change. Further improvement was achieved during follow-up period by continuing the plyometric exercises, all patients being kept on treatment for at least 8 more weeks. It is not known if this continued improvement also would have occurred if plyometric exercises been stopped after the end of the active laser treatment. Most patients started to use the hand during daily activities without complaints.

CONCLUSION

In conclusion, the present study showed that a compination of a 904 nm, 40 mW at 60 HZ, 2.4 J/cm^2 laser, along with plyometric exercises and stretching is more effective than placebo laser and exercise in the treatment of patients with LE. Since this situation is a difficult treating condition, the repetition of the present study is necessary with satisfactory number of patients, in order to strengthen the view of the effectiveness of the proposed protocol.

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