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Research Article

Effects of Low-Level Laser Therapy and Eccentric Exercises in the Treatment of Patellar Tendinopathy

Xiao-Guang Liu,[1] Lin Cheng,[1,2] and Ji-Mei Song[1]

[1] *Laboratory of Laser Sports Medicine, South China Normal University, Guangzhou 510006, China*
[2] *Sichuan University for Nationalities, Sichuan 626001, China*

Correspondence should be addressed to Xiao-Guang Liu; tygx@jnu.edu.cn

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The study aims to investigate if low-level laser therapy (LLLT) combined with eccentric exercises could more effectively treat patellar tendinopathy than LLLT alone and eccentric exercises alone. Twenty-one patients with patellar tendinopathy were randomized to three groups: laser alone, exercise alone, or laser plus exercise, with seven in each group. Laser irradiations were administered at the inferior pole of the patella and the two acupoints of Extra 36 (Xiyan) with the intensity of 1592 mW/cm^2. Eccentric training program consisted of three sets of 15 repetitions of unilateral squat on level ground. All patients received six treatments per week for four weeks. Knee pain and function and quadriceps muscle strength and endurance were evaluated at baseline and the end of treatment. After the 4-week intervention, all groups showed significant improvements in all the outcomes ($P < 0.01$). The laser + exercise group had significantly greater improvements in all the outcomes than the other two groups ($P < 0.05$), except nonsignificant difference in pain relief between the laser + exercise group and the laser group. In conclusion, LLLT combined with eccentric exercises is superior to LLLT alone and eccentric exercises alone to reduce pain and improve function in patients with patellar tendinopathy.

1. Introduction

Patellar tendinopathy is an overuse injury of the patellar tendon and most prevalent in sports involving some form of jumping, such as volleyball, basketball, soccer, and athletics. Patients with patellar tendinopathy clinically manifested activity-related, anterior knee pain associated with focal patellar-tendon tenderness [1, 2]. Histopathological and biochemical evidences indicate that patellar tendinopathy is mainly due to collagen fiber degeneration and inflammation plays a minor role in its pathophysiology [3]. There are many treatment methods for patellar tendinopathy, including anti-inflammatory drugs, massage, eccentric training, low-level laser, ultrasound, surgery, and other modalities [3, 4]. However, no ideal treatment has emerged for the management of patellar tendinopathy.

Eccentric training has proven to be a useful treatment for patellar tendinopathy in a number of randomized controlled trials [5, 6]. Researchers have recommended eccentric training as an important conservative treatment for patellar tendinopathy [4, 7]. However, eccentric training intervention needs a fairly long period and often induces some transient discomfort and pain. To increase efficacy and reduce exercise-induced pain, some adjunctive interventions have been added to eccentric training for treating patellar tendinopathy. Dimitrios et al. [8] have shown that eccentric training and static stretching exercises produced a larger effect than eccentric training alone in the treatment of patellar tendinopathy. In a clinical trial to treat patellar tendinopathy by Cannell et al. [9], cryotherapy was used to reduce pain of the patellar tendon after eccentric drop squats.

Low-level laser therapy (LLLT) has been widely applied in the field of sports medicine. LLLT can exert effects of reducing inflammation and pain and promoting tissues regeneration in the treatment of soft tissue injuries [10–12]. Bjordal et al. [13] and Tumilty et al. [14] have reviewed LLLT for tendinopathy and have founded that LLLT can potentially be effective in treating tendinopathy when recommended dosages are used. Stergioulas et al. [15] have shown that LLLT can accelerate clinical recovery from Achilles tendinopathy when added to an eccentric training regimen. However, it remains unclear whether LLLT can bring about additional benefits to eccentric training in the treatment of patellar tendinopathy.

In the current study, we conducted a randomized controlled trial to investigate if LLLT combined with eccentric exercises could more effectively treat patients with patellar tendinopathy than LLLT alone and eccentric exercises alone.

2. Materials and Methods

The study protocol was approved by the Ethics Committee of the Faculty of South China Normal University, Guangzhou, China. Written informed consent was obtained from each participant prior to the start of treatment.

2.1. Subjects and Groups. Twenty-one patients with patellar tendinopathy aged 18–23 years were enrolled in this study. All patients were male undergraduate students studying at School of Physical Education and Sports Science of South China Normal University. The study was conducted at the Laboratory of Laser Sports Medicine of South China Normal University in Guangzhou in April and May 2013.

The selection criteria for the study were the following [1–3]:

(i) unilateral painful activity-related symptoms from the patellar tendon region for at least three months;

(ii) tenderness with palpation over the inferior pole of the patella;

(iii) no history of trauma to the knee;

(iv) unsuccessful conservative treatment before entering the study, but not in the preceding one month;

(v) no other current knee or lower extremity problems including chondromalacia, muscle strains, and hip or ankle injuries;

(vi) positive decline squat test. This is a clinical diagnostic test.

All patients were randomly divided into three groups: (1) laser group receiving low-level laser treatment alone; (2) exercise group receiving eccentric exercise treatment alone; (3) laser + exercise group receiving low-level laser and eccentric exercise treatment, seven in each group.

2.2. Laser Irradiation Procedure. A GaAlAs laser (Model LD-1, Guangzhou, China) with a continuous output power of 0–500 mW and wavelength of 810 nm was used. The subjects in the laser group and the laser + exercise group received laser irradiations with the intensity of 1592 mW/cm^2 (power: 200 mW, beam diameter: 0.4 cm) at the inferior pole of the patella for 10 minutes and the two acupoints of Extra 36 (Xiyan) medial and lateral to the patellar tendon for 5 minutes each acupoint, once daily, six times per week, for four weeks. The laser irradiations were applied directly to the skin of the points with a perpendicular beam.

2.3. Eccentric Exercise Program. The eccentric training was the same for the exercise group and the laser + exercise group. As eccentric exercises, participants carried out three sets of 15 repetitions of unilateral squat on a flat floor. The squat was performed at a slow speed of 30 counts in 10 seconds at every treatment session [8], following an audio file. As they moved from the standing to the squat position, the quadriceps muscle and patellar tendon by inference were loaded eccentrically; no following concentric loading was done, as the noninjured leg was used to get back to the start position. At the beginning the load consisted of the body weight and participants were standing with all their body weight on the injured leg. The load was increased by 5 kg per week in a backpack. Between each set there was a one-minute rest. After the eccentric training, double lean-back quadriceps stretch was performed as described by Walker [16]. Each stretch lasted one minute. Each training session was to be completed once daily, six times per week, for four weeks. The subjects in the laser + exercise group received the laser treatment after each training session.

2.4. Outcome Measures. Perceived pain, functional capacity of knee, and strength and endurance of the quadriceps muscle were evaluated at baseline and the end of treatment.

Pain intensity was quantified on a 100 mm visual analogue scale (VAS). A modified Victorian Institute of Sport Assessment (VISA) questionnaire was used to evaluate the functional capacity of knee in patients with patellar tendinopathy, which consisted of ten items to cover walking, squatting, standing, running, jumping, weight-bearing movement, training, and sports performance [17]. The range of scores was from 0 to 100 and the highest score represented the maximum of functional capacity.

Maximal isometric strength of the quadriceps muscle was measured in a sitting position with both hip and knee at 90° with a leg extension ergometer (Model NH-3000W, Seoul, Korea). Relative muscle strength was calculated as maximal isometric strength divided by body weight. Quadriceps muscle endurance was evaluated using a single-leg wall squat test. The test was conducted as described by Beck and Norling [18]. During the test, subjects stood comfortably on both feet with their back against av smooth wall. They then slid their back down the wall until a 90° angle at the hip and knee was achieved. One foot was lifted off the ground, at which time the stop watch was started. The watch was stopped when subjects had to return the raised foot to the ground. Measures were taken in seconds.

2.5. Statistical Analysis. Data were expressed as mean ± standard deviation. Differences between before and after treatment in each group were analyzed by paired t-tests. Differences between group means were analyzed using one-way ANOVA with post hoc test. The statistical level of significance was set at $P < 0.05$. SPSS 17.0 statistical software was used for the statistical analysis.

Table 1: Changes in VAS score before and after treatment in all therapy groups.

Group	Before treatment	After treatment	Change over time
Laser	67.86 ± 13.18	15.00 ± 13.54**	52.86 ± 12.20
Exercise	65.71 ± 15.39	19.29 ± 12.93**	46.43 ± 10.69
Laser + exercise	67.86 ± 12.20	5.00 ± 4.08**	62.86 ± 10.35$^{\#}$

Asterisks indicate significant differences from pretreatment ($^{**}P < 0.01$). Crosses indicate significant differences from the exercise group ($^{\#}P < 0.05$).

Table 2: Changes in modified-VISA score before and after treatment in all therapy groups.

Group	Before treatment	After treatment	Change over time
Laser	63.14 ± 9.75	88.14 ± 7.22**	25.00 ± 6.40
Exercise	67.00 ± 10.05	90.71 ± 7.85**	23.71 ± 5.83
Laser + exercise	58.86 ± 12.62	96.57 ± 2.07**	37.71 ± 11.77$^{\triangle\#}$

Asterisks indicate significant differences from pretreatment ($^{**}P < 0.01$). Triangles indicate significant differences from the laser group ($^{\triangle}P < 0.05$). Crosses indicate significant differences from the exercise group ($^{\#}P < 0.05$).

3. Results

3.1. Pain. There were no significant differences for VAS score at baseline between any groups (Table 1). After 4 weeks of intervention, all the groups exhibited significant pain reductions ($P < 0.01$). The mean VAS scores in the laser group, the exercise group, and the laser + exercise group were reduced by 52.86, 46.43, and 62.86 points (percent reductions: 77.9%, 70.1%, and 92.6%), respectively. The proportion of patients who became pain free was 2/7 (28.6%) in the laser + exercise group and 1/7 (14.3%) in the laser group within four weeks. No patient became pain free in the exercise group. The drop of VAS score in the laser + exercise group was significantly greater than in the exercise group. There was no significant difference for VAS score after treatment between the laser group and the exercise group.

3.2. Functional Capacity. There was no difference for modified-VISA score of knee function at baseline between any groups (Table 2). After 4 weeks of intervention, all groups exhibited significant improvements in functional capacity of knee ($P < 0.01$). The mean modified-VISA scores in the laser group, the exercise group, and the laser + exercise group were increased by 25.00, 23.71, and 37.71 points (percentage increment: 39.6%, 35.4%, and 64.1%), respectively. The laser + exercise group showed a significantly greater improvement in functional capacity of knee than the other two groups ($P < 0.05$). There was no significant difference in functional capacity of knee after treatment between the laser group and the exercise group.

3.3. Quadriceps Muscle Strength. There was no difference for relative quadriceps muscle strength at baseline between any groups (Table 3). After 4 weeks of intervention, all groups exhibited significant improvements in quadriceps muscle strength ($P < 0.01$). The mean relative quadriceps muscle strengths in the laser group, the exercise group, and the laser + exercise group were increased by 0.16, 0.19, and 0.31 kg/kg body weight (percentage increment: 42.1%, 50.0%, and 70.5%), respectively. The laser + exercise group had a significantly greater increment in quadriceps muscle strength than the other two groups ($P < 0.05$). There was no significant difference in quadriceps muscle strength after treatment between the laser group and the exercise group.

3.4. Quadriceps Muscle Endurance. There was no difference in quadriceps muscle endurance represented by the wall squat test time at baseline between any groups (Table 4). After 4 weeks of intervention, all groups exhibited significant improvements in quadriceps muscle endurance ($P < 0.01$). The mean times of wall squat test in the laser group, the exercise group, and the laser + exercise group were increased by 22.54, 23.14, and 40.97 seconds (percentage increment: 85.0%, 84.7%, and 149.0%), respectively. The laser + exercise group had a significantly greater improvement in quadriceps muscle endurance than the other two groups ($P < 0.05$). There was no significant difference in quadriceps muscle endurance after treatment between the laser group and the exercise group.

4. Discussion

This randomized controlled study demonstrates that LLLT combined with eccentric training can produce greater improvements in knee pain and function and quadriceps muscle strength and endurance for patients with patellar tendinopathy than LLLT alone and eccentric training alone.

VAS score and VISA-P score have been widely used in orthopedic and sports injury investigations [17, 19, 20]. In this study, pain and function in patients with patellar tendinopathy were evaluated using VAS and modified VISA-P questionnaire, respectively. LLLT and eccentric exercises reduced pain by 77.9% and 70.1% and increased the questionnaire score by 39.6% and 35.4%, respectively, over the 4-week intervention. Although there was no significant difference, LLLT was more effective for pain relief than eccentric exercises in the treatment of patellar tendinopathy. The combination of LLLT and eccentric exercises provided a pain reduction by 92.6% and a function score increment by 64.1% over the treatment period. The results indicated that LLLT can increase effects of

Table 3: Changes in relative quadriceps muscle strength before and after treatment in all therapy groups.

Group	Before treatment	After treatment	Change over time
Laser	0.38 ± 0.04	$0.54 \pm 0.06^{**}$	0.16 ± 0.08
Exercise	0.38 ± 0.10	$0.57 \pm 0.12^{**}$	0.19 ± 0.09
Laser + exercise	0.44 ± 0.14	$0.75 \pm 0.10^{**}$	$0.31 \pm 0.10^{\triangle\#}$

Values are expressed in kg/kg body weight. Asterisks indicate significant differences from pretreatment ($^{**}P < 0.01$). Triangles indicate significant differences from the laser group ($^{\triangle}P < 0.05$). Crosses indicate significant differences from the exercise group ($^{\#}P < 0.05$).

Table 4: Changes in wall squat test time before and after treatment in all therapy groups.

Group	Before treatment	After treatment	Change over time
Laser	26.53 ± 6.79	$49.07 \pm 13.19^{**}$	22.54 ± 14.74
Exercise	27.33 ± 7.06	$50.47 \pm 10.98^{**}$	23.14 ± 12.67
Laser + exercise	27.44 ± 12.65	$68.41 \pm 23.92^{**}$	$40.97 \pm 12.63^{\triangle\#}$

Values are expressed in seconds. Asterisks indicate significant differences from pretreatment ($^{**}P < 0.01$). Triangles indicate significant differences from the laser group ($^{\triangle}P < 0.05$). Crosses indicate significant differences from the exercise group ($^{\#}P < 0.05$).

eccentric exercises on pain relief and functional improvement of knee in the treatment of patellar tendinopathy.

Single-leg wall squat test is a simple isometric strength test to assess quadriceps muscle endurance and has been shown to be reliable and valid in physical fitness assessment [18, 21]. In this study, quadriceps muscle endurance in patients with patellar tendinopathy was measured using the functional test, while quadriceps muscle strength was measured using the leg extension ergometer. With respect to quadriceps muscle endurance, LLLT and eccentric exercises increased the squat test time after treatment by 85.0% and 84.7%, respectively. With respect to quadriceps muscle strength, LLLT and eccentric exercises increased the relative strength after treatment by 42.1% and 50.0%, respectively. Therefore, eccentric exercises seem more effective for strength improvement than LLLT in the treatment of patellar tendinopathy. After the four weeks of treatment, LLLT combined with eccentric exercises increased the squat test time by 149.0% and the relative quadriceps muscle strength by 70.5%, with greater efficacies than LLLT alone and exercise alone. The results indicated that LLLT can increase effects of eccentric exercises on strength and endurance of the quadriceps muscle in the treatment of patellar tendinopathy.

There are some factors influencing efficacy of eccentric exercise for tendinopathy, including eccentric exercise protocol, sports training during the treatment period, and subject's compliance. Some authors advocated that eccentric exercises be performed at a slow speed with mild pain [8, 22, 23]. In contrast, other authors have found exercising without induced pain to be beneficial to healing [24, 25]. This study has adopted the eccentric exercise program at a slow speed without pain and has obtained good results. To avoid painful sports activities is crucial for tendinopathy treatment, because it has been reported that eccentric training is not effective for patellar tendinopathy in volleyball players during the competitive season [26].

In accordance with our results, previous studies have shown that LLLT could exert effects on pain relief and function improvement in the treatment of tendinopathies [15, 27–29]. Bjordal et al. [27] have demonstrated that LLLT can reduce peritendinous prostaglandin E2 (PGE2) concentrations in activated Achilles tendinitis. Therefore, LLLT may reduce pain in patients with tendinopathy through modulating inflammation. On the other hand, the biostimulatory effects of LLLT on collagen fibers synthesis may be responsible for the muscle strength improvement of patients with tendinopathy, because Reddy et al. [30] have shown that LLLT can increase collagen production in healing rabbit Achilles tendon. It is well known that the therapeutic effect of LLLT is dose-dependent [13, 31]. Bjordal et al. [13] have recommended that power densities of LLLT for Achilles, patellar, and elbow tendinopathies be between 2 and 100 mW/cm^2. The results of LLLT trials for tendinopathies with the recommended power densities seem to be consistently positive [15, 27, 32]. Nonsignificant effects of LLLT have been observed in clinical trials for treating elbow tendinopathy with power densities between 100 and 500 mW/cm^2 [33, 34]. However, LLLT with power densities above 1 W/cm^2 has shown positive effects on reducing exercise-induced muscle damage and fatigue in some randomized controlled studies [35–37]. Our results showed that LLLT with an 810 nm GaAlAs laser at 1592 mW/cm^2 was significantly effective in patients with patellar tendinopathy. Of course, further researches are needed to identify the optimal intensity and dose of LLLT in the treatment of patellar tendinopathy.

5. Conclusion

Low-level laser therapy combined with eccentric exercises is superior to low-level laser therapy alone and eccentric exercises alone to reduce pain and improve function in patients with patellar tendinopathy. It is suggested that low-level laser therapy can be used as an important adjunct to eccentric exercises in the treatment of tendinopathies.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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