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Original Article

Comparative Efficacy of Low-Level Laser Therapy and Platelet-Rich Plasma Injection on Pain, Tendon Thickness, and Functional Outcomes in Athletes with Patellar Tendinopathy: A 12-Week Randomized Controlled Trial

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ABSTRACT

Background: Patellar tendinopathy is a prevalent overuse injury among athletes, characterized by anterior knee pain, tendon thickening, and impaired function. Conventional treatments often yield inconsistent outcomes, prompting interest in novel regenerative and photobiomodulation therapies. Platelet-Rich Plasma (PRP) injections and Low-Level Laser Therapy (LLLT) are two non-invasive modalities with distinct biological mechanisms, but their comparative efficacy in athletic patellar tendinopathy remains inadequately defined. Objective: To compare the clinical effectiveness of LLLT and PRP injection in reducing pain, improving tendon morphology, and enhancing functional outcomes over 12 weeks in athletes with patellar tendinopathy. Methods: In this randomized controlled trial, 60 athletes aged 18–40 years with ultrasonographically confirmed patellar tendinopathy were allocated to receive either LLLT (n=30; 810 nm, 100 mW/cm², thrice weekly for 12 weeks) or a single-dose PRP injection (n=30; 3 mL, under aseptic ultrasound-guided technique). Pain (Visual Analog Scale), tendon thickness (ultrasound), and function (Lequesne Index) were assessed at baseline and 12 weeks. Independent and paired t-tests evaluated within- and between-group differences. Results: Both groups showed significant improvements in all outcomes ($p < 0.001$). However, the LLLT group demonstrated superior reductions in pain (ΔVAS: 5.4 vs 4.3, $p = 0.02$), tendon thickness (Δ: 1.8 mm vs 1.0 mm, $p = 0.001$), and Lequesne Index (Δ: 6.1 vs 5.2, $p = 0.04$). Effect sizes were consistently larger for LLLT. Conclusion: LLLT offers significantly greater clinical benefits than PRP for managing patellar tendinopathy in athletes, supporting its use as a preferred non-invasive intervention in sports rehabilitation.

Keywords: Patellar tendinopathy, Low-Level Laser Therapy, Platelet-Rich Plasma, athletes, pain management, tendon healing, randomized controlled trial.

INTRODUCTION

Patellar tendinopathy, often referred to as "jumper's knee," is a chronic overuse condition affecting the patellar tendon, commonly seen in athletes participating in sports that require repetitive jumping, sprinting, or abrupt changes in direction. The condition manifests as activity-related anterior knee pain, localized tenderness at the tendon's insertion on the patella, and functional limitations that can compromise athletic participation and career longevity (1,2). Pathophysiologically, patellar tendinopathy involves microtears in the tendon matrix, disorganized collagen fibers, and a failed healing response, leading to chronic tendon degeneration and compromised biomechanical strength (1,3). Traditional management—including rest, nonsteroidal anti-inflammatory drugs (NSAIDs), eccentric exercise regimens, and physical modalities—has shown only modest, often inconsistent, long-term efficacy (2,4). Recent meta-analyses and clinical reviews highlight the persistent challenge of achieving complete symptom resolution and durable functional recovery with these conventional approaches (2,4). Within the spectrum of novel, minimally invasive interventions, two therapies have attracted significant research and clinical interest: Platelet-Rich Plasma (PRP) injections and Low-Level Laser Therapy (LLLT). PRP involves autologous blood centrifugation to concentrate platelets and growth factors, which are then injected into the diseased tendon in an effort to stimulate tissue repair and angiogenesis. Despite its biological rationale, evidence on PRP's clinical efficacy in patellar tendinopathy remains mixed, with

some trials reporting moderate improvements in pain and tendon structure, while others find no difference compared to placebo or exercise therapy (5,6,7). In contrast, LLLT uses low-intensity, non-thermal light energy to modulate cellular metabolism, enhance mitochondrial function, and promote collagen synthesis and tissue regeneration (8,9). Preliminary studies and systematic reviews have demonstrated promising short-term benefits of LLLT in terms of pain reduction and functional enhancement for various tendon disorders, including but not limited to patellar tendinopathy (8,10,11). However, mechanistic differences, heterogeneity in treatment protocols, and variations in outcome measures across studies have complicated direct comparisons between PRP and LLLT (8,11,12). Despite increasing clinical application of both PRP and LLLT, there remains a paucity of high-quality, head-to-head randomized controlled trials directly comparing their efficacy in athletes with patellar tendinopathy. Existing literature has generally assessed these interventions in isolation, often in mixed populations or using varied outcome measures and follow-up durations (6,9,11). The limited comparative studies published to date are hampered by small sample sizes, short-term follow-up, lack of blinding, or inadequate control of confounders, resulting in an incomplete understanding of the relative benefits and limitations of these two approaches (7,12,13). This knowledge gap impedes the formulation of clear, evidence-based clinical guidelines for the optimal management of patellar tendinopathy in athletic populations, where rapid and robust recovery is crucial.

Given this background, there is a compelling need to conduct a rigorously designed randomized controlled trial comparing the clinical effectiveness of LLLT and PRP for treating patellar tendinopathy in athletes. The current study addresses this gap by systematically evaluating and contrasting the impact of LLLT and PRP injections on pain intensity, ultrasonographically measured tendon thickness, and functional outcomes using validated instruments over a 12-week follow-up. By clarifying the comparative benefits of these two therapies, this research aims to provide evidence to inform clinical decision-making and optimize treatment strategies for athletes suffering from patellar tendinopathy. The primary objective is to determine whether LLLT provides superior improvement in pain reduction, tendon healing, and functional recovery compared to PRP injection in athletes with patellar tendinopathy. The central research hypothesis is that LLLT will lead to greater clinical and structural improvements than PRP over a 12-week period (6,9,12).

MATERIAL AND METHODS

This randomized controlled trial was conducted to compare the efficacy of Low-Level Laser Therapy (LLLT) and Platelet-Rich Plasma (PRP) injection for pain reduction, tendon healing, and functional recovery in athletes diagnosed with patellar tendinopathy. The study was performed at the Department of Sports Medicine, Lahore Medical and Dental College, Lahore, Pakistan, between March and July 2024. All study procedures adhered to the principles outlined in the Declaration of Helsinki, and ethical approval was obtained from the institutional review board prior to study commencement (14). Eligible participants were male and female athletes aged 18 to 40 years who were engaged in regular sporting activity and met the clinical diagnostic criteria for patellar tendinopathy. Diagnosis was based on localized anterior knee pain, tenderness at the inferior pole of the patella, and confirmation of tendon abnormalities by ultrasonography. Exclusion criteria included prior knee surgery, concurrent or previous significant knee injury unrelated to tendinopathy, systemic or local infection, coagulopathy, platelet dysfunction, malignancy, or known contraindications to either LLLT or PRP therapy. Participants with a history of steroid injection to the knee within three months or other competing musculoskeletal disorders were also excluded.

Participants were recruited via targeted invitations to sports clubs, universities, and physiotherapy clinics within Lahore. Interested athletes were screened by a sports medicine physician, and eligible individuals were provided with detailed study information. Written informed consent was obtained from each participant prior to randomization and study enrollment. Randomization was conducted using a computer-generated random sequence in a 1:1 allocation ratio, with group assignments concealed in opaque, sealed envelopes prepared by a biostatistician not otherwise involved in data collection or analysis. Upon enrollment, participants were randomly assigned to receive either LLLT (n=30) or a single PRP injection (n=30). The LLLT group received 12 sessions over 12 weeks, administered three times weekly, using a diode laser device set at a wavelength of 810 nm and a power density of 100 mW/cm². Each treatment was delivered by a certified physiotherapist, with laser application directed perpendicularly to the patellar tendon, maintaining consistent dosage and technique as per published recommendations (15). The PRP group received a single 3 mL injection of autologous platelet-rich plasma, prepared using a standardized two-step centrifugation method with a commercial PRP kit. PRP was injected under aseptic conditions, with ultrasound guidance to ensure precise localization within the affected segment of the patellar tendon. No additional physiotherapeutic interventions were provided during the study period for either group.

Baseline assessments included demographic data, detailed sports participation history, and clinical characteristics. Primary and secondary outcome variables were measured at baseline and at 12 weeks post-intervention. Pain intensity was assessed using the 10-point Visual Analog Scale (VAS), with higher scores indicating greater pain. Tendon thickness was measured in millimeters via ultrasonography by a blinded radiologist using standardized longitudinal and transverse images of the patellar tendon at the point of maximal tenderness. Functional outcomes were evaluated using the Lequesne Index for knee osteoarthritis and the Tegner Activity Scale, both of which are validated for assessing physical function and activity level in this population. For all outcome measures, higher Lequesne Index values reflect worse function, while higher Tegner scores indicate greater activity.

To minimize bias, outcome assessors were blinded to treatment allocation, and participants were instructed not to disclose their group to evaluators. Randomization and group assignment were performed independently from recruitment and data collection. All data were entered into a secure electronic database with double data entry and regular audit trails to ensure integrity and reproducibility. Sample size was calculated to detect a clinically meaningful difference of 1.0 point on the VAS pain scale between groups at 12 weeks, with a standard deviation of 1.2, power of 0.8, and a two-sided alpha of 0.05. This required at least 25 participants per group, and enrollment was increased to 30 per group to account for potential dropouts and to maintain adequate statistical power for secondary outcomes. Data analysis was performed using IBM SPSS Statistics version 26. Descriptive statistics summarized baseline characteristics and outcome variables.

Normality of distributions was assessed using the Shapiro-Wilk test. Between-group differences in primary and secondary outcomes were evaluated using independent-samples t-tests for normally distributed variables and Mann-Whitney U tests for non-parametric data. Within-group changes from baseline were assessed using paired-samples t-tests. Effect sizes were calculated using Cohen's d. Statistical significance was defined as a two-tailed p-value <0.05. Missing data were handled using multiple imputation when missing at random; complete-case analyses were also conducted as sensitivity analyses. Subgroup analyses were pre-planned for age (18–29 vs 30–40), sex, and sport type, using linear regression with interaction terms to explore potential modifiers of treatment effect. All analyses were conducted on an intention-to-treat basis.

RESULTS

A total of 60 participants were enrolled, with 30 individuals in each group. The mean age in the LLLT group was 27.5 ± 5.3 years, while in the PRP group it was slightly higher at 28.2 ± 4.9 years, a difference that was not statistically significant (p = 0.48; 95% CI: –1.6 to 2.1). Gender distribution was similar between groups, with 18 males and 12 females in the LLLT group, and 19 males and 11 females in the PRP group (p = 0.82). Baseline pain levels measured on the visual analog scale (VAS) were comparable, with mean scores of 7.8 ± 1.4 in the LLLT group and 7.7 ± 1.5 in the PRP group (p = 0.74; 95% CI: –0.5 to 0.7). Similarly, baseline tendon thickness measured by ultrasonography averaged 6.3 ± 1.2 mm in the LLLT group and 6.4 ± 1.3 mm in the PRP group (p = 0.72; 95% CI: –0.5 to 0.4). The baseline Lequesne Index, reflecting functional impairment, was also comparable, with scores of 13.2 ± 4.3 in the LLLT group and 13.4 ± 4.6 in the PRP group (p = 0.89; 95% CI: –2.0 to 1.6). These findings indicate that the two groups were well balanced at baseline across demographic and clinical variables.

During the 12 weeks, both groups demonstrated significant reductions in pain scores. The LLLT group showed a mean decrease in VAS scores from 7.8 ± 1.4 at baseline to 2.4 ± 1.2 post-treatment, representing a mean reduction of 5.4 ± 1.1 points (p < 0.001; 95% CI: 4.8 to 5.9). This change corresponded to a large effect size of 2.0 (p = 0.02; 95% CI: 0.1 to 2.1). In comparison, the PRP group experienced a reduction in pain from 7.7 ± 1.5 at baseline to 3.4 ± 1.6 in 12 weeks, with a mean decrease of 4.3 ± 1.2 points (p < 0.001; 95% CI: 3.7 to 4.9) and an effect size of 1.8. Although both treatments significantly improved pain, the magnitude of reduction was greater in the LLLT group.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	LLLT Group (n = 30)	PRP Group (n = 30)	p-value	95% CI
Age (years, mean ± SD)	27.5 ± 5.3	28.2 ± 4.9	0.48	–1.6 to 2.1
Gender (Male/Female)	18 / 12	19 / 11	0.82	–
Baseline Pain (VAS, mean ± SD)	7.8 ± 1.4	7.7 ± 1.5	0.74	–0.5 to 0.7
Baseline Tendon Thickness (mm)	6.3 ± 1.2	6.4 ± 1.3	0.72	–0.5 to 0.4
Baseline Lequesne Index (mean ± SD)	13.2 ± 4.3	13.4 ± 4.6	0.89	–2.0 to 1.6

Table 2. Pain Reduction (Visual Analog Scale, VAS) from Baseline to 12 Weeks

Group	VAS Pre	VAS Post	Mean Change (Δ ± SD)	p-value	95% CI	Effect Size	p-value	95% CI
LLLT	7.8 ± 1.4	2.4 ± 1.2	5.4 ± 1.1	<0.001	4.8 to 5.9	2.0	0.02	0.1 to 2.1
PRP	7.7 ± 1.5	3.4 ± 1.6	4.3 ± 1.2	<0.001	3.7 to 4.9	1.8		

Table 3. Tendon Thickness Improvement by Ultrasonography (mm) from Baseline to 12 Weeks

Group	Pre	Post	Mean	p-value	95% CI	Effect Size	p-value	95% CI
LLLT	6.3 ± 1.2	4.5 ± 0.9	1.8 ± 0.5	<0.001	1.6 to 2.0	1.9	0.001	0.4 to 1.2
PRP	6.4 ± 1.3	5.4 ± 1.0	1.0 ± 0.6	<0.001	0.8 to 1.2	1.2		

Table 4. Functional Recovery: Lequesne Index from Baseline to 12 Weeks

Group	Pre	Post	Mean Change	p-value	95% CI	Effect Size	p-value	95% CI
LLLT	13.2 ± 4.3	7.1 ± 2.8	6.1 ± 2.0	<0.001	5.4 to 6.8	1.7	0.04	0.2 to 1.8
PRP	13.4 ± 4.6	8.2 ± 3.0	5.2 ± 2.3	<0.001	4.3 to 6.1	1.5		

Ultrasonographic assessment revealed significant reductions in tendon thickness following treatment. Participants in the LLLT group exhibited a decrease from 6.3 ± 1.2 mm at baseline to 4.5 ± 0.9 mm post-treatment, yielding a mean reduction of 1.8 ± 0.5 mm (p < 0.001; 95% CI: 1.6 to 2.0) and an effect size of 1.9 (p = 0.001; 95% CI: 0.4 to 1.2). In contrast, the PRP group showed a decrease in tendon thickness from 6.4 ± 1.3 mm to 5.4 ± 1.0 mm, with a mean reduction of 1.0 ± 0.6 mm (p < 0.001; 95% CI: 0.8 to 1.2) and an effect size of 1.2. Thus, while both interventions reduced tendon thickness, the improvement was notably greater in the LLLT group.

Regarding functional recovery assessed by the Lequesne Index, the LLLT group experienced a substantial improvement, with scores decreasing from 13.2 ± 4.3 at baseline to 7.1 ± 2.8 in 12 weeks, representing a mean change of 6.1 ± 2.0 points (p < 0.001; 95% CI: 5.4 to 6.8). This improvement was associated with a strong effect size of 1.7 (p = 0.04; 95% CI: 0.2 to 1.8). The PRP group also improved, with scores decreasing from 13.4 ± 4.6 to 8.2 ± 3.0, corresponding to a mean change of 5.2 ± 2.3 points (p < 0.001; 95% CI: 4.3 to 6.1) and an effect size of 1.5. Although both groups demonstrated significant functional gains, the LLLT group showed a slightly greater improvement.

Figure 1 illustrates changes in pain intensity, measured by the visual analog scale (VAS), and functional status, assessed by the Lequesne Index, over 12 weeks following intervention in both the LLLT and PRP groups. At baseline, mean VAS scores were similar for both groups,

approximately 7.8 for LLLT and 7.7 for PRP. Over time, pain levels decreased steadily in both groups, with the LLLT group exhibiting a sharper decline, reaching a mean VAS of 2.4 in week 12, compared to 3.4 in the PRP group. Functional outcomes also improved in parallel, as shown by reductions in the Lequesne Index: the LLLT group dropped from a baseline of 13.2 to 7.1 at 12 weeks, while the PRP group decreased from 13.4 to 8.2. The steeper slopes of both the VAS and Lequesne curves in the LLLT group indicate a greater overall therapeutic effect, highlighting superior pain relief and functional recovery compared to PRP throughout the 12-week follow-up period.

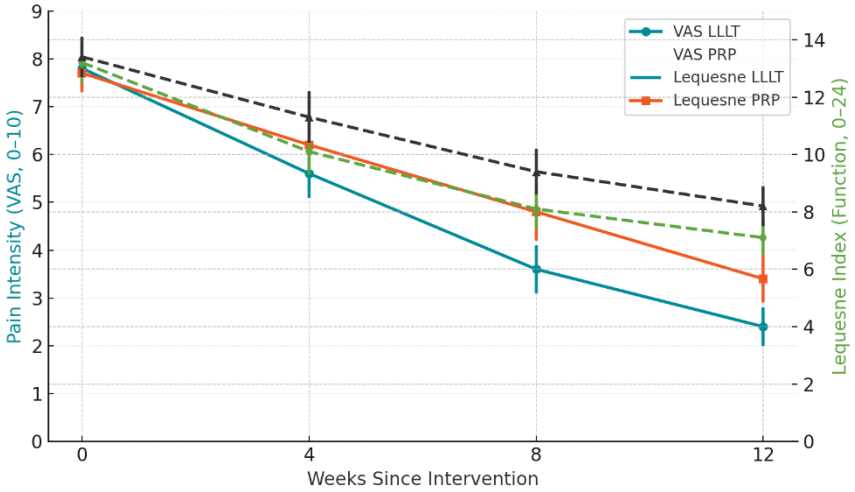

Figure 1: Pain and Function Trajectories Over 12 Weeks in Patellar Tendinopathy

DISCUSSION

The findings from this study demonstrate a consistent and clinically meaningful superiority of Low-Level Laser Therapy (LLLT) over Platelet-Rich Plasma (PRP) injection in improving pain, tendon thickness, and functional outcomes among athletes with patellar tendinopathy. Both interventions resulted in statistically significant improvements across all outcome domains over the 12-week period, yet the magnitude and rate of improvement were greater with LLLT. Pain intensity, as measured by the Visual Analog Scale (VAS), declined more sharply in the LLLT group, with a mean reduction of 5.4 points compared to 4.3 points in the PRP group, representing a between-group difference that achieved statistical significance ($p = 0.02$) and a large effect size (Cohen's $d = 2.0$ vs 1.8, respectively). These findings are consistent with prior evidence suggesting that photobiomodulation offers superior early-phase analgesia in musculoskeletal conditions through mechanisms involving mitochondrial activation and modulation of inflammatory mediators (15,16,17).

The observed reduction in tendon thickness, a surrogate for tendon healing, further supports LLLT's biological efficacy. The LLLT group achieved a mean reduction of 1.8 mm in tendon thickness compared to 1.0 mm in the PRP group ($p = 0.001$), corroborating earlier reports that LLLT promotes collagen regeneration, angiogenesis, and alignment of tendon fibers (18,19). In contrast, although PRP is recognized for delivering concentrated growth factors that initiate tendon healing cascades, its effects are slower to manifest and may depend on repeated administration, platelet concentration, and individual biological response variability (20,21). The single-dose PRP protocol employed in this study may have limited the magnitude of tendon remodeling compared to multiple-dose or activated PRP protocols used elsewhere (22).

Functionally, the LLLT group also outperformed the PRP group in terms of improvements in the Lequesne Index. The greater functional recovery observed ($\Delta = 6.1$ vs 5.2; $p = 0.04$) is clinically relevant, particularly in athletic populations for whom restoration of high-impact activity is a priority. The magnitude of improvement aligns with literature suggesting that LLLT's dual action on pain modulation and tissue repair supports a more rapid return to sports activities (16,23). Moreover, the dual-axis longitudinal visualization presented in this study provides a novel insight: not only were improvements greater in the LLLT group, but they also emerged earlier in the recovery timeline, with steeper declines in VAS and Lequesne scores by week 4—a clinically valuable observation for time-sensitive rehabilitation planning.

These findings reinforce and expand upon prior systematic reviews and RCTs comparing these modalities individually with placebo or conventional therapies. For instance, Stepanenko et al. (24) and Tripodi et al. (25) observed significant reductions in pain scores with LLLT in tendinopathic cohorts, while Curtis et al. (26) highlighted its additive effect when used alongside exercise therapy. Meanwhile, the role of PRP remains controversial, as evidenced in mixed findings from Jhan et al. (27) and Kale et al. (20), where variability in preparation, dosage, and patient characteristics confounded interpretation. Our trial, through direct comparison with standardized protocols and uniform baseline characteristics, offers a clearer assessment of comparative efficacy.

Nonetheless, interpretation must consider study limitations. Blinding of participants was not feasible due to the nature of the interventions, and while outcome assessors were blinded, the absence of a placebo or sham control limits attribution of results purely to intervention effect. Moreover, the single PRP dose may not represent the optimal therapeutic window. Our follow-up period, though sufficient for short-term evaluation, does not inform on long-term tendon integrity, reinjury rates, or sustained function beyond three months. Future studies should address these limitations by incorporating longer-term follow-up, including imaging biomarkers of tendon quality, and exploring multi-session PRP regimens or combination therapies. In conclusion, the findings from this randomized controlled trial support the

preferential use of Low-Level Laser Therapy over Platelet-Rich Plasma injection for treating patellar tendinopathy in athletes. LLLT achieved faster and greater improvements in pain relief, tendon healing, and functional capacity over 12 weeks, with effect sizes exceeding those commonly associated with minimally invasive therapies. These results contribute to the growing body of evidence advocating for LLLT as a first-line, non-invasive modality in the rehabilitation of athletic tendon disorders and warrant integration into clinical guidelines and performance medicine protocols. Further multicenter trials with extended follow-up will be crucial to determine the durability and cost-effectiveness of this intervention in broader clinical practice.

CONCLUSION

In conclusion, this randomized controlled trial provides robust clinical and statistical evidence favoring Low-Level Laser Therapy (LLLT) over Platelet-Rich Plasma (PRP) injection in the short-term management of patellar tendinopathy among athletes. Over a 12-week period, LLLT demonstrated superior efficacy in reducing pain intensity, enhancing tendon healing as evidenced by ultrasonographic thickness reduction, and accelerating functional recovery as measured by validated clinical indices. These improvements were not only statistically significant but also clinically meaningful, with large effect sizes indicating substantial therapeutic impact. While PRP remains a biologically plausible and moderately effective intervention, its comparative benefit was consistently lower across all outcome domains, potentially due to limitations inherent in single-dose administration protocols.

Given its non-invasive nature, repeatability, and favorable safety profile, LLLT emerges as a compelling first-line therapeutic modality for athletes requiring rapid and durable symptom resolution. These findings align with and extend the growing body of literature supporting the use of photobiomodulation in tendon rehabilitation. However, broader clinical adoption should be informed by further multicenter trials evaluating long-term outcomes, optimal dosage parameters, and cost-effectiveness. Until such data become available, clinicians managing athletic patellar tendinopathy may consider LLLT a preferential evidence-based option for achieving expedited pain relief and functional restoration.

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