ORIGINAL ARTICLE

Nr 2025;15 (1):79-90

# Comparative Efficacy of Exercise Therapy *versus* Non Steroidal Anti-Inflammatory Drugs in Treating Lateral Epicondylitis

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**DOI:**
10.32098/mltj.01.2025.10

**LEVEL OF EVIDENCE:** 3

## SUMMARY

**Aim and background**. Lateral epicondylitis (LE), commonly known as tennis elbow, is characterized by pain and reduced elbow function due to overuse of the extensor carpi radialis brevis (ECRB) muscle. This study evaluates the effectiveness of exercise therapy in improving grip strength and electromyography (EMG) patterns of the ECRB muscle in LE patients.
**Materials and methods.** Sixty participants with LE were randomly assigned to two groups: one receiving NSAIDs and home exercises (EG-A) and the other performing specific tennis elbow exercises (EG-B) for 12 weeks. Outcome measures included Pain-Free Grip (PFG), Maximum Grip Strength (MGS), PRTEE, NPRS, and sEMG amplitude of the ECRB muscle. Statistical analysis using SPSS version 20 compared pre- and post-intervention results, with a significance level of 0.05 to evaluate the hypothesis.
**Results**. Significant pain reduction was observed in both groups, with greater reduction in EG-A. Both groups showed improved functionality and symptoms, with more pronounced improvement in EG-A. Grip strength and maximum grip strength increased in both groups, with larger improvements in EG-A. EMG amplitude of muscle activity also notably increased in both groups, with a higher increase in EG-A.
**Conclusions.** The structured exercise therapy program significantly improved grip strength and muscle activation in LE patients. EG-A, which included both conservative treatment and specific exercises, showed greater improvements compared to EG-B, highlighting the effectiveness of tailored exercise interventions in managing LE. These findings advocate for incorporating tailored exercise programs into standard LE treatment protocols to enhance functional recovery and neuromuscular efficiency.

## KEY WORDS

*Lateral epicondylitis; electromyography; forearm extensor tendons; hand grip strength; tennis elbow; NSAIDs.*

## INTRODUCTION

Tennis elbow, known clinically as lateral epicondylitis, poses a significant musculoskeletal challenge affecting individuals across various age groups and activity levels. Characterized by localized pain and tenderness on the outer aspect of the elbow, this condition arises from repetitive strain injuries rooted in the overuse and microtrauma experienced by the tendons of the forearm extensor muscles. Despite its name suggesting a tennis-related origin, tennis elbow extends beyond sport-specific boundaries, impacting not only athletes but also individuals engaged in diverse occupational and recreational activities involving repetitive arm movements and gripping actions. Its ramifications transcend the athletic sphere, affecting a broader demographic engaged in routine repetitive tasks (1).

According to human physiology, a person's ability to carry out everyday tasks and physical activities effectively and resiliently depends heavily on their muscle strength and neuromuscular function. Grip strength is a key measure of general musculoskeletal health and functional capacity among the metrics used to evaluate muscle performance. Meanwhile, surface electromyography (sEMG) offers an advanced way to investigate the complex relationship between brain signals and muscle contractions, illuminating the neuromuscular processes that underpin movement and force production.

Grip strength, the force exerted by the hand and forearm muscles during grasping, is a fundamental aspect of human biomechanics and functionality. It is essential not only for daily activities such as lifting objects and manipulating tools but also as a predictor of overall health and vitality. Research indicates that reduced grip strength is associated with increased mortality risk, functional limitations, and various health conditions, including cardiovascular disease and frailty (2). Moreover, grip strength serves as a proxy for overall muscular strength and functional independence, making it a valuable metric for assessing physical performance across diverse populations. Measurements of grip strength are frequently used to track the progression of lateral epicondylitis (LE). The literature documents several variations of grip strength testing. Healthy subjects demonstrate greater maximal grip strength when tested with the elbow bent at a 90-degree angle compared to an extended elbow position (3, 4).

Electromyography (EMG) is a technique used to record the electrical activity produced by skeletal muscles. This method has been employed to study the function of forearm muscles in both healthy individuals and those with LE. For instance, Rojas observed muscle asymmetry in LE sufferers, indicated by decreased activation of the extensor carpi radialis, increased activation of the extensor carpi ulnaris as a compensatory measure, and a higher muscle exhaustion index compared to control participants (5). By measuring muscle activation patterns, EMG provides valuable insights into the neuromuscular system's response to different stimuli and interventions. Changes in EMG amplitude reflect alterations in motor unit recruitment and firing rates, offering insights into muscle function and performance (6). EMG is instrumental in diagnosing neuromuscular disorders, optimizing rehabilitation protocols, and refining performance training paradigms.

Exercise therapy for LE patients encompasses a range of activities, including resistance training, stretching, flexibility exercises, and neuromuscular re-education. Rooted in the principles of biomechanics, physiology, and motor learning, exercise therapy is a cornerstone of rehabilitation and preventive healthcare interventions. Tailored exercise programs target specific muscle groups, movement patterns, and physiological adaptations to address musculoskeletal injuries, alleviate pain, enhance functional capacity, and optimize athletic performance (7).

Against this backdrop, the present study endeavors to explore the effects of a structured exercise therapy program on grip strength and electromyography amplitude in a targeted population cohort. By administering a comprehensive exercise intervention protocol and employing rigorous outcome assessments, we aim to delineate the nuanced responses of muscular and neuromuscular parameters to therapeutic exercise stimuli. Specifically, we hypothesize that participants undergoing the exercise therapy regimen will demonstrate significant enhancements in grip strength and electromyography amplitude compared to baseline measurements, indicative of improved muscular performance and neuromuscular efficiency.

The goal of this study is to examine changes in the amplitude of the extensor carpi radialis brevis (ECRB) muscles pre- and post-intervention, as assessed by electromyography analysis and dynamometry in participants diagnosed with LE. This evaluation will help determine the suitability of these measures for initial functional assessment and follow-up, given the current lack of relevant assessment instruments for LE.

## MATERIALS AND METHODS

### Ethical approval

The study was approved by the institutional ethical committee, Aligarh Muslim University, Aligarh, India (Ethical approval number: IECJNMC/943 – date of approval: December 29, 2022).

### Subjects

Participants in this study were recruited from the Outpatient Department (OPD) of Orthopaedics at J.N. Medical College, Aligarh Muslim University, specifically tailored for individuals diagnosed with lateral epicondylitis, commonly known as tennis elbow, who were concurrently enrolled in a comparative investigation examining the therapeutic efficacy of two interventions. Initially, a cohort of eighty-four (n = 84) participants indicated interest during the recruitment phase. However, twenty-four (n = 24) participants were subsequently excluded for various reasons: twelve were disqualified due to comorbidities, eight did not meet predefined inclusion criteria, and four chose not to participate. Consequently, a cohort of sixty (n = 60) participants

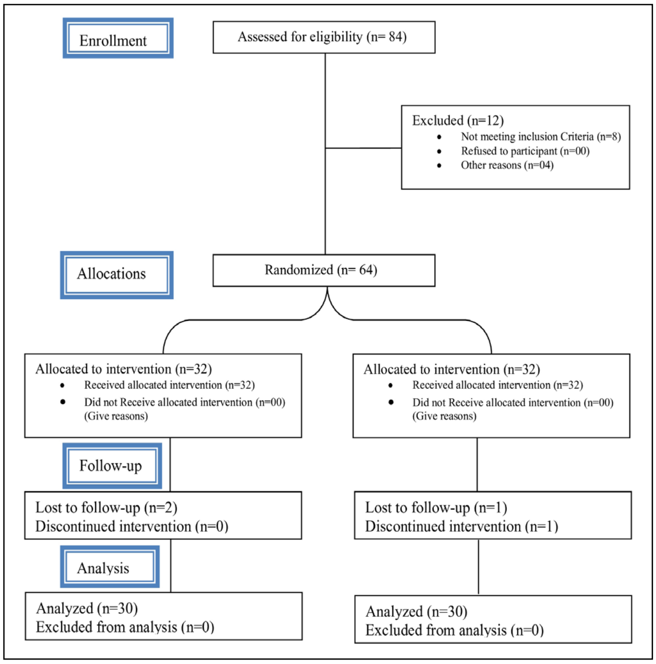


**Figure 1.** Flow diagram showing participants in the study.

completed the baseline and final assessments following a 12-week treatment program (**figure 1**).

## Inclusion criteria

Participants were accepted if they met the inclusion criteria and were recommended for the experimental treatment (augmented soft tissue mobilization). Criteria included individuals displaying typical symptoms of localized pain and tenderness at the anterior inferior aspect of the lateral epicondyle, exacerbated by gripping and wrist extension activities but alleviated by rest (8). Additionally, patients testing positive for Cozen's was included.

## Exclusion criteria

Exclusion criteria encompassed conditions such as elbow dislocation, cervical dysfunction, arthritis affecting the wrist or elbow, carpal tunnel syndrome, upper limb fractures with residual deformity, bilateral lateral epicondylitis, recent corticosteroid injections to the elbow, prior treatment for lateral epicondylitis within the last 3 months, skin-weakening conditions, diabetes, kidney disease, and uncontrolled hypertension.

## Experimental protocol

Sixty (n = 60) subjects were randomly allocated into two groups: experimental group-A (EG-A) and experimental group-B (EG-B), each comprising thirty (n = 30) participants. EG-A received conservative treatment, including daily Non-steroidal anti-inflammatory drugs (NSAIDs) use and prescribed home exercises, while EG-B performed specific tennis elbow home exercises daily for 12 weeks. Outcome measures, including Pain-Free Grip (PFG), Maximum Grip Strength (MGS), Patient-Rated Tennis Elbow Evaluation (PRTEE), Numeric Pain Rating Scale (NPRS), and surface electromyography of Extensor carpi radialis brevis (ECRB) muscle (sEMG) amplitude, were assessed before and after treatment using standardized tools.

## Randomization and blinding

To ensure an unbiased distribution, individuals were randomly allocated to one of two groups: experimental group A (EG-A) or experimental group B (EG-B), each with thirty participants. This allocation was determined using a computer-generated randomization procedure, which ensured that each participant had an equal chance of being assigned to either group. To avoid selection bias, the randomization procedure was concealed until the allocations were finalized.
Blinding was also employed to reduce bias in evaluating the results. Participants were not informed of their specific group assignments (single-blind). Furthermore, the researchers who assessed the outcomes, such as grip strength and pain levels, were blinded to the group assignments (double-blind). This method ensured that the measurements were conducted objectively, without being influenced by the knowledge of group assignments.

## Exercise protocol

Participants in experimental group B (EG-B) performed a series of six daily exercises designed to target the muscles affected by lateral epicondylitis. These exercises adhered to the Frequency, Intensity, Time, and Type (FITT) principle of exercise therapy, focusing on both eccentric and concentric muscle contractions. Eccentric exercises were particularly emphasized due to their well-documented therapeutic benefits in treating lateral epicondylitis. Exercises were performed daily, at a moderate intensity suitable for the participants' fitness levels, and tailored to avoid exacerbating symptoms. Each session lasted for 30 minutes and included both eccentric and concentric muscle contractions.

## Specific exercises

The six exercises included in the protocol were:

- Wrist Extensor Stretch: this static stretch involved straightening the elbow and facing the palm down while gently pulling the fingers back towards the forearm using the opposite hand until a stretch was felt in the wrist extensors. Participants held this position for 30 seconds and repeated it 3 times.

- Wrist Flexor Stretch: another static stretch, this exercise required straightening the elbow and facing the palm up while gently pulling the fingers back towards the forearm using the opposite hand until a stretch was felt in the wrist flexors. Participants held this position for 30 seconds and repeated it 3 times.
- Eccentric Wrist Extension: this eccentric contraction exercise involved holding a small weight (*e.g.*, 1-2 kg), extending the wrist, and then slowly lowering the weight back to the starting position over a period of 3-5 seconds. Participants performed 3 sets of 15 repetitions.
- Concentric Wrist Flexion: this concentric contraction exercise required holding a small weight, flexing the wrist against gravity, and then returning to the starting position. Participants performed 3 sets of 15 repetitions.
- Tennis Ball Squeeze: an isometric contraction exercise where participants squeezed a tennis ball, holding the contraction for 5 seconds before releasing. Participants performed 3 sets of 15 repetitions.
- Supination and Pronation: this dynamic contraction exercise involved holding a light weight and rotating the forearm from a palm-up to a palm-down position and back. Participants performed 3 sets of 15 repetitions.

## Supervision and progression

These exercises were initially supervised by the researcher to ensure correct technique and safety. Participants were instructed to continue these exercises daily for 12 weeks (**figure 2**), gradually increasing the weight or resistance as tolerated to enhance the therapeutic effect (9). The emphasis

| Week | Day | Exercise | Intensity | Duration/Reps | Frequency |
|---|---|---|---|---|---|
| **1-4** | Daily | Rest and Ice | Low | 15-20 min | 3-4x/day |
| | | Wrist Extensor Stretch | Light | 3x15-30 sec each side | 2-3x/day |
| | | Wrist Flexor Stretch | Light | 3x15-30 sec each side | 2-3x/day |
| | | Isometric Wrist Extension | Light | 3x10 sec hold | 2x/day |
| **1-2** | 1-2x/day | Eccentric Wrist Extension | Light | 3x10 reps | 1-2x/day |
| **3-4** | Daily | Eccentric Wrist Extension | Moderate | 3x10-20 reps | Daily |
| | 3x/week | Wrist Flexion with Dumbbell | Light | 3x10-20 reps | 3x/week |
| | | Finger Extensions with Rubber Band | Light | 3x15-20 reps | 3x/week |
| **5-8** | 3x/week | Eccentric Wrist Extension | Moderate | 3x15-25 reps | 3x/week |
| | | Wrist Flexion with Dumbbell | Light | 3x15-20 reps | 3x/week |
| | | Supination / Pronation with Dumbbell | Light | 3x15-20 reps each way | 3x/week |
| | 2x/week | Bicep Curls | Light | 3x15-20 reps | 2x/week |
| **9-12** | 3x/week | Eccentric Wrist Extension | Moderate-High | 3x20-30 reps | 3x/week |
| | | Supination/Pronation with Dumbbell | Moderate-High | 3x20-25 reps each way | 3x/week |
| | | Bicep Curls | Moderate | 3x20-25 reps | 3x/week |
| | | Tricep Extensions | Light | 3x15-20 reps | 3x/week |

**Figure 2.** Periodized training program of twelve weeks.

**Table I.** Descriptive characteristics of subjects.

| Groups | n | Age (years) Mean ± SD | Weight (kg) | Height (cm) | Affected elbow dominant/Non dominant | Affected side Right/Left |
|---|---|---|---|---|---|---|
| EG-A | 30 | 41 ± 4.3 | 68.5 ± 9.48 | 157.23 ± 6.22 | 23/07 | 26/04 |
| EG-B | 30 | 42.66 ± 2.91 | 73.1 ± 5.51 | 155.22 ± 5.23 | 24/06 | 25/05 |

EG-A: Experimental Group-A; EG-B: Experimental Group-B.

on eccentric exercises was due to their proven efficacy in treating tendinopathies, including lateral epicondylitis.

### Outcome measures

The Numeric Pain Rating Scale (NPRS) ranged from 0 to 10 for pain assessment, while the Patient-Rated Tennis Elbow Evaluation (PRTEE) provided a standardized quantitative evaluation of pain and functional impairment (39). The Pain-Free Grip (PFG) was measured using a digital dynamometer in two positions, with three measurements averaged for repeatability. Maximum Grip Strength (MGS) was assessed similarly (10, 11).

Surface electromyography (EMG) recordings were conducted to monitor the activity of the extensor carpi radialis muscle during five-second maximal wrist extension contractions. A sample frequency of 1000 Hz was employed for all EMG acquisition sessions, in accordance with established literature recommendation (12). Bilateral application of two surface electrodes (Biometric DataLogMWX8) was performed following standard protocol, which involved cleaning and shaving the electrode insertion sites, with the reference electrode placed over the olecranon serving as ground. Participants assumed a seated position with their elbows bent at a 90-degree angle. To mitigate the risk of fatigue, a two-minute rest period was observed between each contraction. Three measurements were taken. Signal pre-amplification at the source was conducted with a gain of 100 to minimize motion artifacts. Subsequently, the EMG signals were filtered using root mean square (RMS), rectified to absolute values, and smoothed using a moving average of 10 points to remove noise. The maximum value of each rectified curve was identified, and the mean of the three maximum values was calculated.

## RESULTS

In this study, sixty (n = 60) participants were divided into two groups of thirty each and analyzed using SPSS version 20. To compare the initial and week 12 evaluations, paired t-tests ($\alpha = 0.05$) were conducted on several measures: the Numeric Pain Rating Scale (NPRS), Patient-Rated Tennis Elbow Evaluation (PRTEE), Pain-Free Grip (PFG) in kilograms, Maximum Grip Strength (MGS) in kilograms, and the electromyography (EMG) amplitude of the Extensor Carpi Radialis Brevis (ECRB) muscle. Independent t-tests ($\alpha = 0.05$) were then used to assess post-treatment differences between Experimental Group A (EG-A) and Experimental Group B (EG-B) for these measures. Additionally, effect sizes were calculated using Eta-Square to determine the magnitude of the observed differences.

The study presents the outcomes of the exercise therapy intervention aimed at assessing improvements in grip strength and extensor carpi radialis brevis muscle (ECRB) electromyography (EMG) patterns in two experimental groups. The objective of the study was to understand the effectiveness of the intervention in enhancing grip strength and analyzing carpi radialis brevis muscle (ECRB) electromyography (EMG) patterns among individuals with affected elbows.

### Descriptive characteristics

**Table I** presents the descriptive characteristics of the participants, with 30 subjects in each group. Both groups had similar age distributions: EG-A had a mean age of 41 ± 4.3 years, while EG-B had a mean age of 42.66 ± 2.91 years. In terms of physical characteristics, EG-B participants had a slightly higher mean weight (73.1 kg ± 5.51) compared to EG-A (68.5 kg ± 9.48). Conversely, EG-A participants were marginally taller (157.23 cm ± 6.22) than those in EG-B (155.22 cm ± 5.23). The distribution of affected elbows (dominant/non-dominant) and affected sides (right/left) was similar in both groups. This suggests that any observed differences in outcomes are less likely to be influenced by demographic or physical traits, thereby supporting the reliability of comparing the effectiveness of the interventions.

### Intervention effects

**Table II** displays the pre- and post-intervention data for the NPRS, PRTEE, PFG, MGS, and EMG amplitude, revealing significant improvements across all measures for both EG-A and EG-B. **Table III** presents the paired sample differences

**Table II.** Descriptive statistics for Patients NPRS, PRTEE, PFG (Kg), MGS (Kg), EMG amplitude.

| Variables | Groups | | Mean ± SD | Std Error Mean |
|---|---|---|---|---|
| Numeric Pain Rating Scale (NPRS) | EG-A | Pre | 5.86 ± 1.04 | 0.19 |
| | | Post | 2.20 ± 0.40 | 0.74 |
| | EG-B | Pre | 5.93 ± 0.63 | 0.11 |
| | | Post | 2.66 ± 0.66 | 0.12 |
| Patient-Rated Tennis Elbow Evaluation (PRTEE) | EG-A | Pre | 47.16 ± 1.85 | 0.33 |
| | | Post | 12.93 ± 1.74 | 0.31 |
| | EG-B | Pre | 47.36 ± 1.56 | 0.28 |
| | | Post | 15.56 ± 0.93 | 0.17 |
| Pain-Free Grip Strength (PFG) (Kg) | EG-A | Pre | 9.45 ± 1.16 | 0.21 |
| | | Post | 18.61 ± 1.88 | 0.34 |
| | EG-B | Pre | 9.38 ± 1.18 | 0.21 |
| | | Post | 16.64 ± 1.47 | 0.26 |
| Maximum Grip Strength (MGS) (Kg) | EG-A | Pre | 19.02 ± 2.08 | 0.38 |
| | | Post | 33.65 ± 2.01 | 036 |
| | EG-B | Pre | 18.43 ± 1.81 | 0.33 |
| | | Post | 29.22 ± 2.17 | 0.39 |
| (ECRB) elec-tromyography (EMG) Ampli-tude (µV) | EG-A | Pre | 211.48 ± 68.03 | 12.42 |
| | | Post | 432.36 ± 50.01 | 9.13 |
| | EG-B | Pre | 215.48 ± 70.20 | 12.81 |
| | | Post | 380.94 ± 42.28 | 7.71 |

EG-A: Experimental Group-A; EG-B: Experimental Group-B.

**Table III.** Comparison of NPRS, PRTEE, PFG (Kg), MGS (Kg), and amplitude mean between pre- and post-training programs.

| Variables | | Groups | Paired Difference | | | t-value | P-value | Eta-Square ($\eta^2$) |
|---|---|---|---|---|---|---|---|---|
| | | | Mean difference | SD | Std Error mean | | | |
| Numeric Pain Rating Scale (NPRS) | Pre-test - Post test | EG-A | 3.66 | 1.12 | 0.20 | 17.86 | 0.00 | 0.91 |
| | Pre-test - Post-test | EG-B | 3.26 | 0.69 | 0.12 | 25.87 | 0.00 | 0.95 |
| Patient-Rated Tennis Elbow Evaluation (PRTEE) | Pre-test - Post-test | EG-A | 34.23 | 3.08 | 0.56 | 60.84 | 0.00 | 0.99 |
| | Pre-test - Post-test | EG-B | 31.80 | 1.71 | 0.31 | 101.85 | 0.00 | 0.99 |
| Pain-Free Grip Strength (PFG) (Kg) | Pre-test - Post-test | EG-A | 9.1 | 1.5 | 0.27 | 32.79 | 0.00 | 0.97 |
| | Pre-test - Post-test | EG-B | 7.26 | 1.52 | 0.26 | 26.05 | 0.00 | 0.95 |
| Maximum Grip Strength (MGS) (Kg) | Pre-test - Post-test | EG-A | 14.62 | 2.01 | 0.36 | 39.79 | 0.00 | 0.98 |
| | Pre-test - Post-test | EG-B | 10.79 | 2.74 | 0.50 | 21.52 | 0.00 | 0.94 |
| (ECRB) EMG Amplitude (µV) | Pre-test - Post-test | EG-A | 220.88 | 65.11 | 11.88 | 18.57 | 0.00 | 0.92 |
| | Pre-test - Post-test | EG-B | 165.45 | 69.07 | 12.61 | 13.11 | 0.00 | 0.85 |

EG-A: Experimental Group-A; EG-B: Experimental Group-B; df = 29.

**Table IV.** Comparison of NPRS, PRTEE, PFG (Kg), MGS (Kg), and amplitude mean between Experimental Group A (EG-A) and Experimental Group B (EG-B) before the training program.

| Variables | Groups | Independent t test | | | t-value | P-value | Eta-Square ($\eta^2$) |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Std Error mean | | | |
| Numeric Pain Rating Scale (NPRS) | EG-A | 5.86 | 1.04 | 0.19 | -0.29 | 0.76 | 0.001 |
| | EG-B | 5.93 | 0.63 | 0.11 | | | |
| Patient-Rated Tennis Elbow Evaluation (PRTEE) | EG-A | 47.16 | 1.85 | 0.33 | -0.45 | 0.65 | 0.003 |
| | EG-B | 47.36 | 1.56 | 0.28 | | | |
| Pain-Free Grip Strength (PFG) (Kg) | EG-A | 9.45 | 1.16 | 0.21 | 0.24 | 0.80 | 0.000 |
| | EG-B | 9.38 | 1.18 | 0.22 | | | |
| Maximum Grip Strength (MGS) (Kg) | EG-A | 19.02 | 2.08 | 0.38 | 1.16 | 0.25 | 0.022 |
| | EG-B | 18.43 | 1.81 | 0.33 | | | |
| (ECRB) EMG Am-plitude (μV) | EG-A | 211.48 | 68.03 | 12.42 | -0.22 | 0.82 | 0.000 |
| | EG-B | 215.48 | 70.20 | 12.81 | | | |

EG-A: Experimental Group-A; EG-B: Experimental Group-B; n = 60; df = 58.

**Table V.** Comparison of NPRS, PRTEE, PFG (Kg), MGS (Kg), and amplitude mean between Experimental Group A (EG-A) and Experimental Group B (EG-B) post training program.

| Variables | Groups | Independent t test | | | t-value | P-value | Eta-Square ($\eta^2$) |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Std Error mean | | | |
| Numeric Pain Rating Scale (NPRS) | EG-A | 2.20 | 0.40 | 0.07 | -3.29 | 0.00 | 0.15 |
| | EG-B | 2.66 | 0.66 | 0.12 | | | |
| Patient-Rated Tennis Elbow Evaluation (PRTEE) | EG-A | 12.93 | 1.74 | 0.31 | -7.29 | 0.00 | 0.47 |
| | EG-B | 15.56 | 0.93 | 0.17 | | | |
| Pain-Free Grip Strength (PFG) (Kg) | EG-A | 18.61 | 1.88 | 0.34 | 4.50 | 0.00 | 0.25 |
| | EG-B | 16.64 | 1.47 | 0.26 | | | |
| Maximum Grip Strength (MGS) (Kg) | EG-A | 33.65 | 2.00 | 0.36 | 8.18 | 0.00 | 0.53 |
| | EG-B | 29.22 | 2.17 | 0.39 | | | |
| (ECRB) EMG Am-plitude (μV) | EG-A | 432.36 | 50.01 | 9.13 | 4.30 | 0.00 | 0.24 |
| | EG-B | 380.94 | 42.28 | 7.71 | | | |

EG-A: Experimental Group-A; EG-B: Experimental Group-B; n = 60; df = 58.

for these outcome variables between Experimental Groups A and B, assessed using paired sample t-tests to evaluate the changes from pre-test to post-test within each group following the interventions or treatments.

## Pain reduction and functional improvement

The NPRS scores showed a significant decrease in pain levels for both groups from pre- to post-intervention. EG-A experienced a greater reduction compared to EG-B. The mean reduction in NPRS for EG-A was 3.66 ($t = 17.86$, $p < 0.05$) with an Eta-Square of 0.91, indicating a large effect size. For EG-B, the mean reduction was 3.26 ($t = 25.87$, $p < 0.05$) with an Eta-Square of 0.95, also showing a large effect size. Similarly, PRTEE scores, which assess pain and functional impairment, showed significant decreases, with EG-A showing a mean difference of 34.23 ($t = 60.84$, $p < 0.05$)

and an Eta-Square of 0.99, and EG-B showing a mean difference of 31.80 ($t = 101.85$, $p < 0.05$) and an Eta-Square of 0.99. These reductions indicate improved functionality and reduced symptoms post-intervention, with EG-A exhibiting a more pronounced improvement.

### Grip strength improvement

In terms of grip strength, both groups showed significant increases from pre- to post-intervention. For Pain-Free Grip (PFG), EG-A had a mean increase of 9.1 kg ($t = 32.79$, $p < 0.05$) with an Eta-Square of 0.94, and EG-B had a mean increase of 7.26 kg ($t = 26.05$, $p < 0.05$) with an Eta-Square of 0.95. Maximum Grip Strength (MGS) also improved significantly, with EG-A showing a mean increase of 14.62 kg ($t = 39.79$, $p < 0.05$) and an Eta-Square of 0.98, and EG-B showing a mean increase of 10.79 kg ($t = 21.52$, $p < 0.05$) and an Eta-Square of 0.96. These results suggest that the intervention was effective in enhancing grip strength, with EG-A showing greater improvements.

### Muscle activity enhancement

EMG amplitude of the ECRB muscle showed significant increases from pre- to post-intervention for both groups. EG-A exhibited a mean increase of 220.88 volts ($t = 18.57$, $p < 0.05$) with an Eta-Square of 0.85, while EG-B showed a mean increase of 165.45 volts ($t = 13.11$, $p < 0.05$) with an Eta-Square of 0.92. This increase in muscle activity suggests that the intervention effectively enhanced the functional capacity of the ECRB muscle, with EG-A demonstrating a higher increase in EMG amplitude compared to EG-B (**figure 3**).

### Pre-Intervention Comparisons

**Tables IV** and **V** illustrate the comparative analysis of outcomes between Experimental Group A (EG-A) and Experimental Group B (EG-B) before and after the intervention. Initially, the two groups showed no significant differences across various pre-test measures, including the Numeric Pain Rating Scale (NPRS), Patient-Rated Tennis Elbow Evaluation (PRTEE), Pain-Free Grip (PFG), Maximum Grip Strength (MGS), and electromyography (EMG) amplitude. This lack of significant difference indicates that the two groups were comparable at baseline, ensuring that any post-intervention differences could be attributed to the interventions rather than pre-existing disparities.

### Post-intervention comparisons

Post-intervention analysis revealed significant improvements in all measured outcomes for both groups, with EG-A consistently outperforming EG-B. EG-A demonstrated a greater reduction in pain levels, with a mean Numeric Pain Rating Scale (NPRS) score of 2.20 (SD = 0.40) compared to EG-B's 2.66, with a t-value of -3.29 ($p < 0.05$) and an effect size (Eta-Square) of 0.15. For the Patient-Rated Tennis Elbow Evaluation (PRTEE), which measures both pain and functional impairment, EG-A showed significantly better improvement, indicating substantial functional gains and symptom reduction. In terms of grip strength, EG-A's Pain-Free Grip (PFG) increased to 18.61 kg, whereas EG-B's was 16.64 kg, with a t-value of 4.50 ($p < 0.05$) and an Eta-Square of 0.25, suggesting a moderate effect size. For Maximum Grip Strength (MGS), EG-A achieved 33.65 kg compared to EG-B's 29.22 kg, with a t-value of 8.18 ($p < 0.05$) and an Eta-Square of 0.53, indicating a large effect size. Regarding muscle activity, the electromyography (EMG) amplitude of the ECRB muscle showed a higher increase in EG-A than in EG-B, with EG-A having a mean amplitude of 432.36 volts compared to EG-B's 380.94 volts, with a t-value of 4.30 ($p < 0.05$) and an Eta-Square of 0.24, indicating a significant difference with a moderate effect size. These findings suggest that the intervention in EG-A was more effective in reducing pain, enhancing grip strength, and increasing

**Figure 3.** Calculating of grip strength and muscle activation.

## DISCUSSION

The present study aimed to assess the efficacy of an exercise therapy intervention in strengthening grip strength and electromyography (EMG) patterns of the extensor carpi radialis brevis (ECRB) muscle in individuals with tennis elbow. The results from the experimental groups (EG-A and EG-B) provide valuable insights into the effects of the intervention on various outcome parameters.

Pre- and post-intervention assessments revealed significant improvements in elbow functionality, pain-free grip strength, maximum grip strength, and ECRB muscle EMG for both EG-A and EG-B. These findings highlight the effectiveness of the exercise therapy intervention in enhancing elbow function and grip strength among individuals with tennis elbow. Before the intervention, there were no statistically significant differences between EG-A and EG-B regarding pain, pain-free grip strength, and maximum grip strength, suggesting that the baseline characteristics of the two groups were similar. However, post-intervention comparisons revealed significant differences between EG-A and EG-B in these measures, with EG-A consistently showing greater improvements. These results suggest that the specific exercise therapy employed in EG-A led to more favorable outcomes compared to the intervention in EG-B.

In alignment with the current investigation's outcomes, the effectiveness of eccentric training of wrist extensors combined with supinator strengthening (32). The results indicated that this combination led to a graded increase in surface electromyography activity in the extensor carpi radialis brevis (ECRB) (32). Ongoing clinical studies aim to determine whether this approach is also effective for treating lateral epicondylitis (LET). Alfredson *et al.* (33) were the first to propose eccentric training for injured tendons, and this method has since become the most widely used conservative treatment for tendinopathy. Peterson *et al.* (13) conducted a randomized controlled trial comparing exercise *versus* a wait-list control in chronic tennis elbow cases. Their findings revealed that individuals in the exercise group experienced a more pronounced and expedited reduction in pain levels, both during muscle contraction and elongation phases (14). Similarly, previous studies, including those by Khan *et al.* (14) and Ohberg *et al.* (15), have indicated that structured exercise training tends to alleviate pain and enhance functionality (14, 15). Almquist *et al.* provided insights into the effectiveness of various treatment approaches by reporting percentage improvements in pain and grip strength within each group (16). Balk *et al.* conducted a comprehensive analysis encompassing pain relief, symptom recurrence, satisfaction, and return to work percentages, crucial for a thorough evaluation of treatment outcomes (17). Boyd and McLeod's study offered a multifaceted perspective on patient outcomes, focusing on pain relief, range of motion, and grip strength (18). Calvert *et al.* detailed percentages across various outcome measures, indicating overall treatment success and patient satisfaction (19). Cummins' examination of pain management in different activities provided valuable insights into the effectiveness of various interventions (21). Dunkow *et al.* utilized DASH scores, patient satisfaction, and return to work rates to standardize the assessment of treatment efficacy (21). Together, these studies offer a holistic understanding of lateral epicondylitis treatment outcomes, guiding clinical decision-making and enhancing patient care strategies.

Conversely, other researchers have highlighted the efficacy of stretching and strengthening exercises, administered once or more daily, three days per week for durations exceeding six weeks, in alleviating pain. However, the associated improvement in grip strength remains less conclusive, as evidenced by investigations conducted by Smidt *et al.* (22) and Trudel *et al.* (23).

A Swedish study proposed by Svernlov suggested that a 12-week exercise program incorporating eccentric training and static stretching yielded notable reductions in pain levels and concurrent increases in grip strength among lateral epicondylitis patients (24). The rationale behind eccentric strengthening lies in its capacity to impose load on the musculotendinous unit, thereby promoting hypertrophy and augmenting tensile strength. Consequently, this approach mitigates tendon strain during physical activities. Additionally, eccentric contraction has been identified as a potent stimulus for tendon cell activity, fostering collagen production and bolstering the tendon's resilience against external forces. Furthermore, recent research has underscored the role of eccentric strengthening in diminishing neovascularization, a purported contributor to pain in lateral epicondylitis and other tendon pathologies (25).

The study shows that the exercise program used in EG-A significantly improves grip strength and reduces pain in tennis elbow patients, supporting the effectiveness of exercise-based interventions for lateral epicondylitis. Comparing exercise therapy with other treatments, such as percutaneous electrolysis and traditional physical therapy, percutaneous electrolysis has proven effective for tendinopathies including lateral epicondylitis (34, 35). Additionally, combining virtual reality therapy (VT) and physical exercise (PE) into an exercise program (EE) effectively treats pain, range of motion (ROM), pressure pain threshold (PPT), and overall function in patients with lower extremity (LE) conditions (36, 37).

Eccentric exercises are effective for treating tendinopathies like lateral epicondylitis. They work by loading the musculotendinous unit, promoting muscle growth, tensile strength, and collagen production, which enhances tendon resilience. Studies by Alfredson *et al.* (33) and Kaux *et al.* (38) show significant pain reduction and improved function with these exercises. They also help reduce neovascularization, a factor in tendon pain. However, some patients find it challenging to adhere to these programs due to the discomfort involved. These findings highlight the versatility and effectiveness of exercise therapy, while also emphasizing the need for further research to optimize treatment protocols for lateral epicondylitis.

The pre- and post-intervention assessments revealed notable enhancements in elbow electromyography (EMG) amplitude of the extensor carpi radialis brevis (ECRB) muscle for both Experimental Group A (EG-A) and Experimental Group B (EG-B). The ECRB is conventionally regarded as a primary contributor to wrist extension, while the extensor digitorum communis (EDC) and extensor carpi ulnaris (ECU) are thought to act synergistically in this movement (26). These outcomes underscore the efficacy of the exercise therapy intervention in improving muscle strength among individuals with elbow-related impairments.

Prior to the intervention, no significant differences in EMG amplitude were observed between EG-A and EG-B, indicating equitable baseline characteristics and facilitating a valid comparison of intervention effects. Following the intervention, significant differences emerged between EG-A and EG-B across all measured parameters. A higher EMG recording of the ECRB was found in participants of EG-A's post-rehabilitation program, indicating greater muscle activation for the same force compared to those in EG-B. Notably, EG-A consistently demonstrated superior improvements in muscle activity compared to EG-B. As a result, more motor units needed to be activated to achieve a certain force, and a higher EMG recording was acquired due to the increased recruitment of motor units (27). These variations suggest that the specific exercise therapy program implemented in EG-A yielded more favorable outcomes compared to the intervention in EG-B.

Previous studies have conclusively demonstrated the effectiveness of various therapeutic interventions, such as medication, electrical and thermal modalities, cold massage, cross-friction massage, and steroid transcutaneous injection, in the treatment of chronic lateral epicondylitis (28,29). Our research outcomes, indicating variance in muscle activation within pre- and post-exercise programs, align with prior observations (30). Traditional treatment techniques did not directly address the issue of compromised tensile strength. Progressively overloading the tendon over time through eccentric exercises would lead to an increase in tensile strength (31). Moreover, this treatment can be performed as part of a home program and does not require continued medical supervision.

In light of these facts, we conclude that the therapeutic eccentric exercise training stimulates tendon remodeling and produces muscular adaptive responses, leading to reduced pain and improved grip strength in individuals with lateral epicondylitis.

### Clinical significance

The findings of this study have important implications for clinical practice. They suggest that tailored exercise therapy interventions can effectively alleviate pain, improve elbow function, and enhance muscle strength in individuals with affected elbows. Moreover, the study highlights the importance of individualized treatment approaches, as interventions yielding superior outcomes can be identified and implemented in clinical settings.

### Limitations and future directions

Despite the valuable insights provided by this study, several limitations should be considered. The lack of a control group limits the ability to attribute the observed improvements solely to the exercise therapy intervention. Future research incorporating a control group and longer follow-up periods could provide further clarification on the intervention's long-term efficacy. Additionally, the study's sample size was relatively small, warranting validation of the findings in larger cohorts.

## CONCLUSIONS

This study highlights the clinical relevance of tailored exercise therapy in treating lateral epicondylitis (LE). Our evaluation demonstrated that exercise therapy significantly improves grip strength and reduces pain in individuals with elbow impairments. Both experimental groups (EG-A and EG-B) exhibited notable enhancements in elbow functionality, pain-free grip strength, maximum grip strength, and electromyography (EMG) activity following the intervention. Although there were no significant baseline differences between groups, EG-A consistently showed superior improvements in grip strength and pain reduction. These results suggest that the specific exercise regimen used in EG-A was more effective. The findings are consistent with previous research, which supports various therapeutic interventions for chronic lateral epicondylitis, particularly highlighting eccentric exercise training as a promising approach for pain alleviation and grip strength enhancement. Therefore, incorporating tailored exercise therapy into standard treatment protocols for LE is strongly recommended.

## FUNDINGS

None.

## DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

## CONTRIBUTIONS

JAP, MAB, AQK: conceptualization. AA, SS, JAP: writing – original draft. AQK, MAB BI: writing review & editing. JAP: visualization.

## ACKNOWLEDGEMENTS

The authors are grateful to the Aligarh Muslim University, Aligarh (U.P.) India 202002.

## CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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