

EFFECT OF MOBILIZATION WITH MOVEMENT WITH TENDON
VIBRATION FEEDBACK VERSUS HEAVY SLOW RESISTANCE TRAINING
ON PAIN, GRIP STRENGTH, AND FUNCTIONAL OUTCOMES IN
ATHLETES WITH LATERAL EPICONDYLITIS

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Abstract

Background: Lateral epicondylitis is a common musculoskeletal condition characterised by lateral elbow pain, reduced grip strength, and impaired upper-limb function. This study compared the effects of Mobilisation with Movement combined with Tendon Vibration (MWM + TV) and Heavy Slow Resistance (HSR) training on pain, grip strength, and functional outcomes in athletes with lateral epicondylitis.

Methods: A randomised controlled trial was conducted among 52 athletes aged 20–40 years with lateral epicondylitis. Participants were randomly allocated into two equal groups (n = 26) at the Outpatient Department of Advance Physiotherapy and Sports Clinic, DHA, Lahore. Group A received HSR training, whereas Group B received MWM combined with Tendon Vibration. Both interventions were administered three times weekly for four weeks. Pain intensity, grip strength, and functional disability were assessed using the Numeric Pain Rating Scale (NPRS), Jamar Hand Dynamometer, and Patient-Rated Tennis Elbow Evaluation (PRTEE), respectively. Data were analysed using IBM SPSS Statistics version 26. Normality was assessed using the Shapiro–Wilk test, followed by paired-samples t-test, independent-samples t-test, and one-way analysis of variance (ANOVA), as appropriate.

Results: Both groups demonstrated statistically significant improvements in all outcome measures following the intervention ($p < 0.001$). In the HSR group, NPRS scores decreased from 6.81 ± 1.833 to 4.38 ± 1.602 , while grip strength increased from 19.04 ± 3.243 to 23.46 ± 4.091 kg. PRTEE scores decreased from 54.65 ± 7.848 to 20.38 ± 4.011 . In the MWM + TV group, NPRS scores decreased from 6.58 ± 1.880 to 2.46 ± 1.630 , while grip strength increased from 20.46 ± 3.679 to 28.15 ± 3.171 kg. PRTEE scores decreased from 52.31 ± 7.347 to 23.08 ± 3.212 . Between-group analysis demonstrated significantly lower post-intervention NPRS scores and greater grip strength in the MWM + TV group ($p < 0.001$), whereas

significantly lower PRTEE scores were observed in the HSR group ($p = 0.010$).

Conclusion: Both HSR and MWM combined with Tendon Vibration produced significant improvements in pain, grip strength, and functional outcomes in athletes with lateral epicondylitis. MWM + TV demonstrated greater improvement in pain reduction and grip strength, whereas HSR produced greater improvement in PRTEE scores.

1. INTRODUCTION

Lateral epicondylitis (LE), commonly known as tennis elbow, is a prevalent musculoskeletal disorder characterised by pain over the lateral elbow, particularly during gripping and resisted wrist extension. It is commonly associated with repetitive loading of the wrist extensor muscles and is frequently observed in individuals involved in repetitive occupational or sporting activities [1,2]. Although traditionally considered an inflammatory condition, LE is primarily a degenerative tendinopathy involving microtearing, collagen disorganisation, and angiofibroblastic changes, with the extensor carpi radialis brevis (ECRB) tendon being most frequently affected [3]. These pathological changes reduce tendon load-bearing capacity and may result in persistent pain, reduced grip strength, and functional impairment [4].

LE affects approximately 1–3% of the general population, while higher prevalence has been reported among individuals exposed to repetitive wrist-extension activities [5]. Tennis players are particularly susceptible, with reported career prevalence ranging from 40–60%, largely because of repetitive mechanical loading during gripping and upper-limb movements [6]. Occupational and ergonomic factors, including manual labour, prolonged computer use, repetitive forearm movements, inadequate sporting technique, insufficient warm-up, inappropriate equipment, and muscle imbalance, may further increase the risk of LE [7]. Pain and impaired grip strength can restrict lifting, gripping, carrying, and other activities of daily living, consequently affecting athletic performance, participation, and quality of life [8,9].

Conservative management commonly includes activity modification, rest, non-steroidal anti-

inflammatory drugs, counterforce bracing, and physiotherapy. Although these approaches may reduce symptoms and mechanical loading, recurrence and incomplete functional recovery remain common concerns [10,11]. Physiotherapy interventions such as stretching, therapeutic exercise, ultrasound, and transcutaneous electrical nerve stimulation are widely used; however, the persistent nature of tendinopathy highlights the need for interventions that address both symptoms and tendon capacity [11].

Mobilisation with Movement (MWM), developed by Brian Mulligan, combines sustained accessory joint mobilisation with active physiological movement. In LE, MWM has been used to reduce pain and improve grip strength and functional performance. Its proposed effects include correction of minor positional faults, stimulation of joint mechanoreceptors, and activation of neurophysiological pain-modulation mechanisms [11,12]. The addition of tendon vibration may provide supplementary proprioceptive and neuromuscular input, potentially enhancing extensor muscle activation and functional performance [12].

Heavy Slow Resistance (HSR) is an exercise-based approach involving progressive, controlled loading through concentric and eccentric contractions of the forearm extensor musculature, including the ECRB, extensor carpi radialis longus, and extensor digitorum [12]. Progressive loading may promote tendon adaptation and remodelling through increased collagen synthesis, improved collagen organisation, and enhanced tensile capacity, thereby improving the functional capacity of the musculotendinous unit [13]. Previous evidence has demonstrated beneficial effects of HSR in tendinopathies, including

reductions in pain and improvements in strength and functional performance [14].

MWM and HSR target LE through different but potentially complementary mechanisms. MWM primarily provides immediate symptomatic and functional benefits through manual mobilisation and neurophysiological mechanisms, whereas HSR emphasises progressive tendon loading and longer-term structural adaptation [11–14]. Tendon vibration combined with MWM may further enhance proprioceptive feedback and grip performance, whereas HSR may provide greater benefits for tendon capacity and sustained functional recovery.

Despite the clinical use of both approaches, comparative evidence regarding MWM combined with tendon vibration and HSR in athletic populations remains limited. In particular, the additional effect of tendon vibration during MWM has received comparatively little investigation. Therefore, this study was conducted to compare the effects of MWM with tendon vibration feedback and HSR training on pain, grip strength, and functional outcomes in athletes with lateral epicondylitis.

2. CRITICAL ANALYSIS

The reviewed literature provides evidence that both exercise-based and manual therapy approaches can improve pain, grip strength, and functional outcomes in patients with lateral epicondylitis. HSR has demonstrated beneficial effects on grip strength, PRTEE, pain, and functional capacity, supporting its role in progressive tendon loading and rehabilitation [14,16,17]. Similarly, studies investigating MWM have reported significant improvements in pain, grip strength, and functional performance, with MWM showing favourable outcomes when combined with exercise or other conservative interventions [12,13,18]. Eccentric exercise-based rehabilitation has also produced improvements in pain, grip strength, and function, further supporting the importance of mechanical loading in LE management [9]. However, these findings should be interpreted in the context of differences

in intervention protocols, treatment duration, outcome measures, and patient characteristics.

Several methodological limitations reduce the direct applicability of the existing evidence to athletic populations. Most studies recruited patients with lateral epicondylitis from general clinical populations rather than athletes, despite the greater repetitive loading and functional demands experienced during sports [9,12–19]. Sample sizes were also relatively small in some investigations, while short intervention or follow-up periods limited conclusions regarding sustained treatment effects [12,13,15,19]. The feasibility study by Sveinall et al. additionally highlighted adherence challenges associated with HSR, which may influence the effectiveness of exercise-based rehabilitation [16]. Other interventions, including HPLT, radial nerve self-mobilisation, MET, IASTM, and conventional exercise, demonstrated improvements in LE outcomes but did not provide direct comparisons between MWM, tendon vibration, and HSR [9,15,18,19]. Consequently, the available literature supports the individual use of these rehabilitation strategies but provides limited evidence regarding their comparative effectiveness.

A major gap therefore remains concerning the combined use of MWM with tendon vibration feedback compared with HSR, particularly among athletes with lateral epicondylitis. Existing MWM studies primarily examine manual mobilisation alone or in combination with conventional exercise, whereas HSR studies focus predominantly on progressive tendon loading [12–14,17,18]. Tendon vibration may provide additional proprioceptive and neuromuscular feedback, but its specific contribution when combined with MWM has not been adequately established. Moreover, previous studies have used different populations, protocols, and outcome measures, making direct comparison difficult [9,12–19]. The present study addresses this gap by directly comparing MWM with tendon vibration feedback and HSR training using pain, grip strength, and functional outcomes in athletes with lateral epicondylitis.

3. OBJECTIVES AND HYPOTHESIS

The objective of this study was to compare the effects of Mobilisation with Movement with tendon vibration feedback versus Heavy Slow Resistance (HSR) training on pain, grip strength, and functional outcomes in athletes with lateral epicondylitis. The null hypothesis (H_0) stated that there would be no significant difference between the two interventions in terms of pain, grip strength, and functional outcomes, whereas the alternate hypothesis (H_1) stated that a significant difference would exist between the interventions in these outcomes.

4. METHOD AND MATERIAL

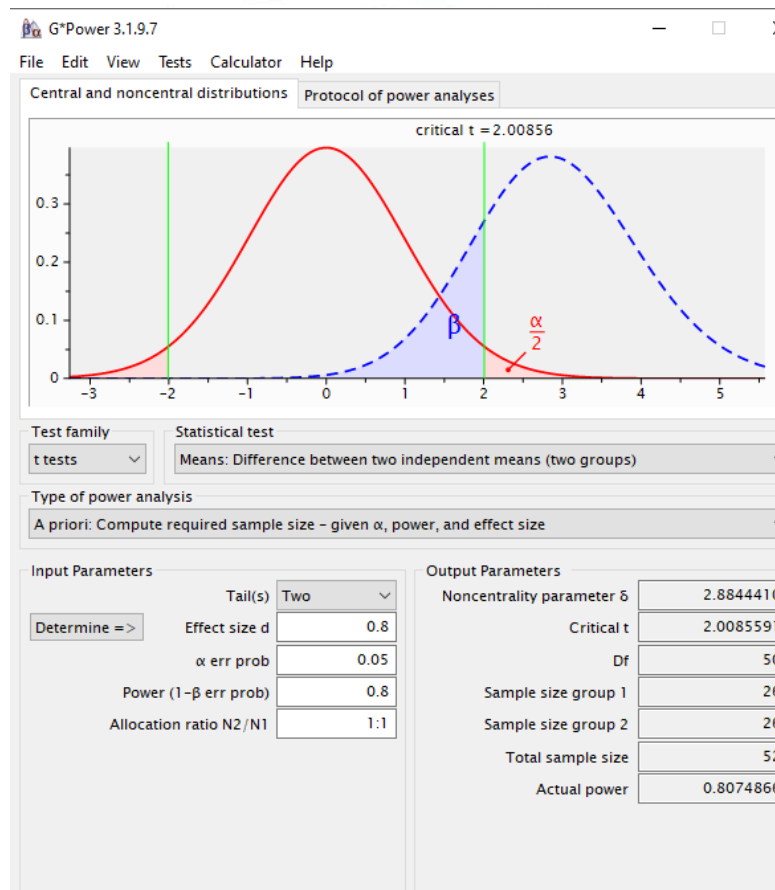
4.1 Study Design, Setting, and Sample Size

The study was designed as a randomised clinical trial (RCT) and was conducted in the Outpatient

Department (OPD) of Advance Physiotherapy and Sports Clinic, DHA, Lahore. The sample size was calculated using G*Power software version 3.1.9.7, based on a two-tailed difference between two independent means, with an effect size of 0.80, $\alpha = 0.05$, and statistical power of 0.80. The calculated sample size was 52 participants, with 26 participants allocated to each group [20].

4.2 Study Population, Diagnostic Procedure, and Duration

The study included athletes aged 20–40 years with clinically diagnosed lateral epicondylitis who attended the physiotherapy OPD. A total of 52 eligible participants were randomly allocated into two equal groups ($n = 26$).



The diagnosis was established on the basis of clinical history, symptom characteristics,

palpation, and provocative testing. Participants were required to have unilateral lateral elbow pain

for at least six weeks, localised tenderness over the lateral epicondyle and/or common extensor tendon, and pain aggravated by gripping, lifting, resisted wrist extension, or repetitive wrist and forearm movements. Cozen's and Mill's tests were performed to support the clinical diagnosis. In Cozen's test, the participant sat with the elbow flexed approximately 90° and forearm pronated and performed active wrist extension against resistance. Reproduction of familiar lateral elbow pain indicated a positive test. In Mill's test, the elbow was extended with the forearm pronated, while the wrist and fingers were passively flexed to stretch the wrist extensors. Reproduction of familiar lateral elbow pain indicated a positive response.

Clinical diagnosis was based on the overall presentation rather than a single test. Participants were also screened for differential diagnoses, including cervical radiculopathy, radial tunnel syndrome, elbow osteoarthritis, ligamentous injury or instability, fracture, systemic inflammatory arthropathy, and other relevant elbow disorders. Previous fracture, surgery, or trauma involving the affected upper extremity was also documented.

The total study duration was six months following approval of the research synopsis. Recruitment, baseline assessment, intervention, post-intervention assessment, and data collection were completed within this period. The intervention was administered for four weeks, with baseline assessment conducted before treatment and post-intervention assessment performed at the end of the fourth week.

4.3 Sampling Technique and Selection Criteria

A non-probability consecutive sampling technique was used. Eligible participants fulfilling the predefined inclusion and exclusion criteria were recruited consecutively until the required sample size was achieved.

Participants were included if they were athletes aged 20–40 years with a clinical diagnosis of lateral epicondylitis based on history, physical examination, and provocative testing; had unilateral lateral elbow pain lasting at least six

weeks, localised tenderness over the lateral epicondyle and/or common extensor tendon, and pain aggravated by gripping, lifting, resisted wrist extension, or repetitive wrist and forearm movements; demonstrated reproduction of familiar pain during at least one provocative test (Cozen's or Mill's test) and pain or sensitivity during resisted wrist-extensor activity; and provided written informed consent with willingness to comply with the study procedures. Participants were excluded if they had a previous fracture, surgery, or significant trauma involving the affected upper extremity or elbow; systemic inflammatory or rheumatological disease, neurological disorders of the upper limb, cervical radiculopathy, radial tunnel syndrome, elbow osteoarthritis, ligamentous instability, or other elbow pathology accounting for symptoms; bilateral lateral elbow symptoms; physiotherapy for the affected elbow or corticosteroid injection within the previous three months; or any other condition likely to interfere with the assessment of pain, grip strength, or upper-limb function.

4.4 Procedure of Data Collection

A total of 52 participants meeting the predefined inclusion and exclusion criteria were recruited after providing written informed consent and were equally allocated to the MWM + TV and HSR groups ($n = 26$ each). Following eligibility confirmation and baseline assessment, participants were randomly assigned in a 1:1 ratio using a computer-generated randomisation sequence prepared by an independent individual who was not involved in recruitment, intervention delivery, or outcome assessment. Allocation concealment was maintained using sequentially numbered, sealed, opaque envelopes, which were opened by designated staff immediately before intervention after completion of baseline measurements. The outcome assessor was blinded to group allocation and had no involvement in randomisation or intervention delivery. Before data collection, the assessor received standardised training in the administration and scoring of the Numeric Pain Rating Scale (NPRS), grip strength assessment, and Patient-Rated Tennis Elbow

Evaluation (PRTEE), including participant instructions, positioning, measurement procedures, and outcome recording. Pre-testing was conducted to standardise the assessment procedures. Participants were instructed not to disclose their treatment allocation during outcome assessment, and the assessor independently recorded all measurements.

4.5 Data Collection Tools

Numeric Pain Rating Scale (NPRS)

Pain intensity was assessed using the 11-point NPRS, ranging from 0 (no pain) to 10 (worst possible pain). Scores of 1–3, 4–6, and 7–10 indicate mild, moderate, and severe pain, respectively. The NPRS is simple to administer and has demonstrated high reliability, with reliability coefficients of 0.95–0.96 [21].

Patient-Rated Tennis Elbow Evaluation (PRTEE)

Pain and functional disability were assessed using the 15-item PRTEE, comprising five pain items (maximum score 50) and 10 function items (maximum score 100). The overall score ranges from 0–100 and is calculated as **(Pain Score + Function Score) ÷ 2**; lower scores indicate less pain and disability. Severity is classified as mild (0–24), moderate (25–49), severe (50–74), and very severe (75–100). The PRTEE demonstrates high reliability (ICC 0.93–0.96; Cronbach's α 0.88–0.96), good construct and convergent validity, with correlations of $r = 0.85$ with DASH and $r = 0.61–0.74$ with VAS. Its reported minimal clinically important difference (MCID) is 11–15 points [22].

Grip Strength (Jamar Hand Dynamometer)

Grip strength was measured using a Jamar Hand Dynamometer to assess maximum voluntary isometric grip force. Participants were seated with the elbow at 90° and forearm in a neutral position, with the grip span adjusted according to hand size. Three maximal contractions were performed for 3–5 seconds each, and the mean value was recorded in kilograms or pounds. Reported normative grip strength values in healthy adults

are approximately 40–60 kg for men and 20–40 kg for women, depending on age and demographic characteristics. The Jamar dynamometer demonstrates high reliability, with ICC values ranging from 0.85–0.98 when standardised procedures are followed [23,24].

4.6 Intervention Protocol

All participants received their respective interventions for four weeks, with three supervised sessions per week on alternate days. Interventions were delivered by trained physiotherapists according to standardised protocols covering participant positioning, treatment technique, dosage, progression, rest intervals, symptom monitoring, and safety. Both groups also received intervention-specific home exercises. Attendance, exercise progression, and treatment modifications were documented throughout the intervention period. As both groups received supervised treatment and a corresponding home exercise programme, the interventions were considered multicomponent rehabilitation programmes; therefore, the study compared the overall MWM + TV and HSR programmes rather than the isolated effects of individual components.

GROUP A: MOBILISATION WITH MOVEMENT WITH TENDON VIBRATION FEEDBACK

Participants in Group A received MWM combined with tendon vibration three times weekly for four weeks. The participant sat with the affected elbow flexed at 20°–30°, forearm pronated, and wrist in a neutral position. The therapist applied a sustained posterolateral glide to the radial head while the participant actively extended the wrist. The movement was performed within a pain-free or minimally symptomatic range, with pain maintained at $\leq 2/10$ on the NPRS. MWM was performed for three sets of eight repetitions with a 30-second rest interval between sets. Tendon vibration was applied to the common extensor tendon approximately 2–3 cm distal to the lateral epicondyle using a handheld therapeutic vibration device at 80 Hz for 10 minutes. Additional supervised exercises included

wrist extension, gripping, and forearm supination. The home programme consisted of wrist extension with a dumbbell and finger extension using a resistance band, performed for three sets of 15 repetitions. Resistance was progressed according

to technique, tolerance, and symptom response. The detailed intervention protocol is presented in Table 1.

Table 1. Intervention Protocol for Group A

Component	Intervention Details
Patient position	Sitting; elbow flexed 20°–30°, forearm pronated, wrist neutral
Therapist position	Standing on affected side
MWM technique	Sustained posterolateral radial-head glide during active wrist extension
Movement range	Pain-free or minimally symptomatic
Pain limit	≤2/10 NPRS
Tendon site	Common extensor tendon, 2–3 cm distal to lateral epicondyle
Vibration frequency	80 Hz
Vibration duration	10 minutes
MWM dosage	3 sets × 8 repetitions
Rest interval	30 seconds between sets
Supervised frequency	3 sessions/week on alternate days
Intervention duration	4 weeks
Additional exercises	Wrist extension, gripping, and forearm supination
Home exercises	Wrist extension with dumbbell and finger extension with resistance band
Home dosage	3 sets × 15 repetitions
Progression	Resistance increased according to tolerance, technique, and symptom response
Safety	Treatment modified if pain exceeded the predefined limit

Note. MWM = Mobilization With Movement; NPRS = Numeric Pain Rating Scale.

GROUP B: HEAVY SLOW RESISTANCE TRAINING

Group B received HSR training three times weekly on alternate days for four weeks, with each supervised session lasting 30–40 minutes. The programme comprised concentric–eccentric wrist extension, wrist flexion, and radial deviation performed with the forearm supported and wrist freely mobile using dumbbells or resistance bands. Each repetition was performed at a controlled tempo of 3 seconds concentric and 3 seconds eccentric. Four sets of 6–8 repetitions were completed for each exercise, with 2 minutes of rest between sets. Initial resistance was 1–2 kg, based on baseline strength, exercise technique, and

symptom tolerance, while exercise-related pain was maintained at ≤3/10 on the NPRS. Resistance was increased by 0.5 kg when eight repetitions were completed in all sets with appropriate technique and acceptable symptoms; otherwise, the resistance was maintained or reduced. No 1-repetition maximum testing was performed. The home programme included wrist extension, wrist flexion, radial deviation, and finger extension, with progression based on tolerance and technique. Symptoms were monitored during treatment and the following morning. The detailed HSR intervention protocol is presented in Table 2.

Table 2. Intervention Protocol for Group B

Component	Intervention Details
Exercises	Wrist extension, wrist flexion, and radial deviation
Patient position	Sitting with forearm supported and wrist freely mobile
Equipment	Dumbbells or resistance bands
Initial resistance	1–2 kg
Repetition tempo	3 seconds concentric + 3 seconds eccentric
Dosage	4 sets × 6–8 repetitions per exercise
Rest interval	2 minutes between sets
Pain limit	≤3/10 NPRS
Supervised frequency	3 sessions/week on alternate days
Session duration	30–40 minutes
Intervention duration	4 weeks
Progression criterion	Completion of 8 repetitions in all sets with proper technique and acceptable symptoms
Progression	0.5 kg increase when criterion was achieved
Load adjustment	Resistance maintained or reduced if repetitions could not be completed or symptoms increased
1RM testing	Not performed
Home exercises	Wrist extension, wrist flexion, radial deviation, and finger extension
Home progression	Resistance progressed according to tolerance and technique
Safety monitoring	Symptoms assessed during treatment and the following morning
Supervision	Technique, positioning, resistance, and symptom response monitored by a trained physiotherapist

Note. NPRS = Numeric Pain Rating Scale; 1RM = one-repetition maximum. Resistance progression was based on repetition completion, exercise technique, and symptom tolerance rather than 1RM testing.

4.7 Intervention Supervision and Standardisation

All interventions were delivered by trained physiotherapists according to standardised protocols. Therapists were trained in patient positioning, MWM technique, radial-head glide, tendon vibration application, exercise technique, dosage, repetition tempo, rest intervals, pain limits, and resistance progression. The same intervention sequence and prescribed dosage were maintained throughout the four-week treatment period. Adjustments to movement range or resistance were made according to predefined symptom and performance criteria and documented by the treating physiotherapist. Participants were monitored during each supervised session for pain aggravation, exercise

difficulty, and adverse events, while adherence to supervised and home-based exercises was recorded.

4.8 Adherence, Protocol Deviations and Adverse Events

Attendance at supervised sessions and adherence to the prescribed home exercise programme were documented throughout the intervention. Protocol deviations, treatment discontinuation, symptom aggravation, and adverse events were recorded by the investigator. Pain-related changes were monitored using participant reporting and the NPRS, and treatment or exercise progression was modified when predefined symptom limits were exceeded. The procedures for adherence and safety monitoring are summarised in Table 3.

Table 3. Adherence and Safety Monitoring

Parameter	Assessment Method
Supervised-session attendance	Attendance record
Home-exercise adherence	Participant report/exercise record
Protocol deviations	Investigator documentation
Intervention discontinuation	Recorded throughout treatment
Adverse events	Monitored and documented during treatment
Symptom aggravation	NPRS and participant report
Treatment modification	Documented when required

Note. NPRS = Numeric Pain Rating Scale.

4.9 Data Analysis

Data were entered and analysed using IBM SPSS Statistics version 26. Continuous variables were summarised as mean $\pm$ standard deviation (SD), while categorical variables were presented as frequencies and percentages. The Shapiro-Wilk test was used to assess the normality of continuous data. Within-group pre- and post-intervention comparisons were performed using the paired-samples *t* test, while between-group differences were assessed using the independent-samples *t* test. Effect sizes were calculated to determine the magnitude of treatment effects. Statistical

significance was set at $p < .05$.

4.10 Ethical Considerations

Ethical approval was obtained from the Institutional Review Board (IRB) before commencement of the study. Written informed consent was obtained from all participants after explaining the study purpose, procedures, potential risks, and benefits. Participant privacy and confidentiality were maintained throughout the study. Participants were informed of their right to withdraw from the study at any stage without penalty or adverse consequences.

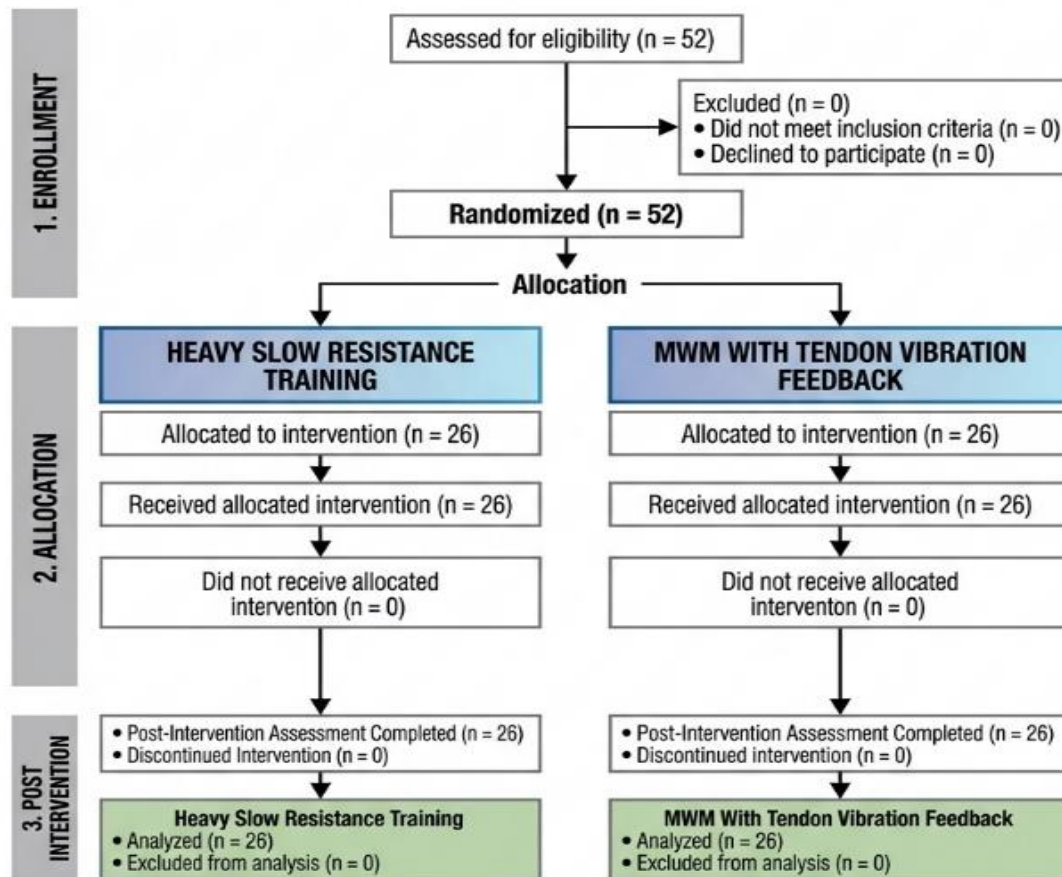


Figure 1: CONSORT flow diagram depicting the screening, randomization, intervention allocation, post-intervention assessment, and final analysis for Heavy Slow Resistance Training versus MWM With Tendon Vibration Feedback.

5. DATA ANALYSIS AND RESULTS

Table 4

Demographic Characteristics of Participants by Intervention Group

Variable	Category	HSR (Group A), n (%)	MWM + Tendon Vibration (Group B), n (%)
Age (years)	Mean $\pm$ SD	31.54 $\pm$ 5.65	35.46 $\pm$ 2.92
Gender	Male	12 (46.2%)	20 (76.9%)
	Female	14 (53.8%)	6 (23.1%)
Affected elbow	Right	6 (23.1%)	12 (46.2%)
	Left	20 (76.9%)	14 (53.8%)
Total		26 (100%)	26 (100%)

Note. HSR = Heavy Slow Resistance; MWM = Mobilization With Movement; SD = standard deviation.

Interpretation:

Table 4 presents the demographic characteristics of the 52 participants, with 26 participants in each intervention group. The mean age was 31.54 $\pm$

5.65 years in the HSR group and 35.46 $\pm$ 2.92 years in the MWM + tendon vibration group. The HSR group comprised 12 males (46.2%) and 14 females (53.8%), whereas the MWM + tendon

vibration group comprised 20 males (76.9%) and 6 females (23.1%). Regarding the affected elbow, left-sided involvement was more frequent in the HSR group (76.9%), while the MWM + tendon

vibration group showed a relatively more balanced distribution, with 46.2% having right-sided and 53.8% having left-sided involvement.

Table 5

Pre- and Post-Treatment Pain Intensity, Grip Strength, and PRTEE Scores by Treatment Group

Outcome Measure	Treatment Group	Pre-treatment Mean $\pm$ SD	Post-treatment Mean $\pm$ SD
Pain intensity (NPRS)	HSR	6.81 $\pm$ 1.833	4.38 $\pm$ 1.602
	MWM + Tendon Vibration	6.58 $\pm$ 1.880	2.46 $\pm$ 1.630
Grip strength (kg)	HSR	19.38 $\pm$ 3.01	23.46 $\pm$ 4.09
	MWM + Tendon Vibration	21.01 $\pm$ 2.21	28.15 $\pm$ 3.17
PRTEE score	HSR	54.65 $\pm$ 7.848	20.38 $\pm$ 4.011
	MWM + Tendon Vibration	52.31 $\pm$ 7.347	23.08 $\pm$ 3.212

Note. HSR = Heavy Slow Resistance; MWM = Mobilization With Movement; TV = Tendon Vibration; NPRS = Numeric Pain Rating Scale; PRTEE = Patient-Rated Tennis Elbow Evaluation; SD = standard deviation. Lower NPRS and PRTEE scores indicate lower pain/disability, whereas higher grip-strength values indicate greater strength.

Table 5 presents the pre- and post-treatment scores for pain intensity, grip strength, and PRTEE in both treatment groups. In the HSR group, NPRS scores decreased from 6.81 $\pm$ 1.833 to 4.38 $\pm$ 1.602, while grip strength increased from 19.38 $\pm$ 3.01 kg to 23.46 $\pm$ 4.09 kg. PRTEE scores also decreased from 54.65 $\pm$ 7.848 to 20.38 $\pm$ 4.011. In the MWM + tendon vibration group, NPRS scores decreased from 6.58 $\pm$ 1.880 to 2.46 $\pm$ 1.630, while

grip strength increased from 21.01 $\pm$ 2.21 kg to 28.15 $\pm$ 3.17 kg. PRTEE scores decreased from 52.31 $\pm$ 7.347 to 23.08 $\pm$ 3.212. The graphical representation of the pre- and post-treatment findings is presented in Figure 1. Overall, both groups demonstrated improvement in pain, grip strength, and functional status following treatment.

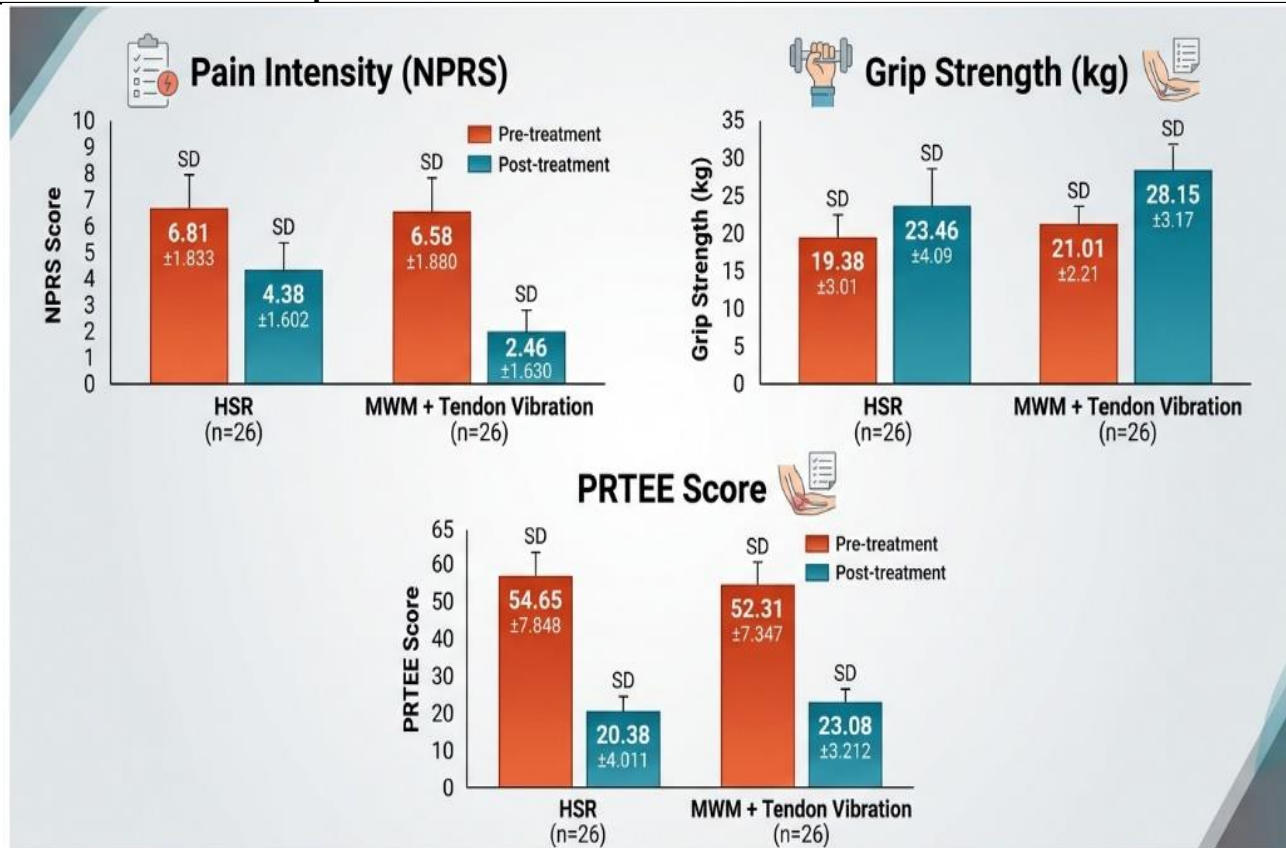


Figure 1 Comparison of Pre- and Post-Treatment Pain, Grip Strength, and PRTEE Scores Between Treatment Groups

Table 6

Tests of Normality Using the Shapiro-Wilk Test

Variable	Statistic	df	Sig. (p)
Baseline Grip Strength	.961	52	.084
Pre-treatment PRTEE	.959	52	.073
Baseline Pain (NPRS)	.960	52	.076

Note. PRTEE = Patient-Rated Tennis Elbow Evaluation; NPRS = Numeric Pain Rating Scale; df = degrees of freedom.

Table 6 presents the Shapiro-Wilk test results for the baseline outcome variables. Baseline grip strength ($p = .084$), pre-treatment PRTEE ($p = .073$), and baseline NPRS ($p = .076$) all showed p

values greater than .05, indicating no statistically significant departure from normality. Therefore, the data met the normality assumption and parametric statistical tests were considered appropriate for subsequent analysis.

Table 7

Paired-Samples t-Test for Pre- and Post-Treatment Outcomes

Outcome Measure	Pre-treatment Mean	Post-treatment Mean	Mean Difference	p-value
NPRS	6.69	3.42	3.27	< .001
Grip strength (kg)	21.73	25.81	4.08	< .001
PRTEE	53.48	21.73	31.75	< .001

Note. NPRS = Numeric Pain Rating Scale; PRTEE = Patient-Rated Tennis Elbow Evaluation. Mean difference represents the absolute change between pre- and post-treatment values.

Table 7 demonstrates statistically significant changes in all assessed outcomes following treatment. NPRS decreased from 6.69 to 3.42, with a mean reduction of 3.27 points ($p < .001$), indicating a significant reduction in pain intensity. Grip strength increased from 21.73 kg to 25.81 kg, with a mean improvement of 4.08 kg ($p < .001$), indicating improved hand-grip strength. PRTEE

scores decreased from 53.48 to 21.73, with a mean reduction of 31.75 points ($p < .001$), indicating significant improvement in pain and functional disability. Overall, the combined analysis demonstrates statistically significant pre- to post-treatment improvement in pain, grip strength, and functional status.

Table 8

Between-Group Comparison of NPRS, Grip Strength, and PRTEE Scores

Outcome	Time	HSR, M ± SD	MWM + Tendon Vibration, M ± SD	Mean Difference	p	Effect Size
NPRS	Pre-treatment	6.81 ± 1.83	6.58 ± 1.88	1.923	.656	1.190
	Post-treatment	4.38 ± 1.60	2.46 ± 1.63	1.923	< .001	1.190
Grip strength (kg)	Pre-treatment	19.38 ± 3.01	21.01 ± 2.21	-4.692	.141	-1.282
	Post-treatment	23.46 ± 4.09	28.15 ± 3.17	-4.692	< .001	-1.282
PRTEE	Pre-treatment	54.65 ± 7.85	52.31 ± 7.35	-2.692	.271	-0.741
	Post-treatment	20.38 ± 4.01	23.08 ± 3.21	-2.692	< .001	-0.741

Note. HSR = heavy slow resistance; MWM = mobilization with movement; NPRS = Numeric Pain Rating Scale; PRTEE = Patient-Rated Tennis Elbow Evaluation. Lower NPRS and PRTEE scores indicate lower pain/disability, whereas higher grip-strength values indicate greater strength. M = mean; SD = standard deviation.

Table 8 shows that the HSR and MWM + tendon vibration groups were comparable at baseline, with no statistically significant differences in NPRS ($p = .656$), grip strength ($p = .141$), or PRTEE ($p = .271$). Following the four-week intervention,

significant between-group differences were observed for all outcomes ($p < .001$). The MWM + tendon vibration group had lower post-treatment NPRS scores (2.46 ± 1.63 vs. 4.38 ± 1.60) and higher grip strength (28.15 ± 3.17 kg vs. $23.46 \pm$

4.09 kg), whereas the HSR group had a lower PRTEE score (20.38 ± 4.01 vs. 23.08 ± 3.21). These findings indicate significant between-group

differences in pain, grip strength, and functional disability following treatment.

Table 9

Between-Group Comparison of Baseline and Post-Treatment Outcomes Using One-Way ANOVA

Variable	Group	M	SD	95% CI	Mean Square	F	p
Baseline NPRS	HSR	6.81	1.83	[6.07, 7.55]	0.69	0.20	.656
	MWM + Tendon Vibration	6.58	1.88	[5.82, 7.34]	—	—	—
Post-Treatment NPRS	HSR	4.38	1.60	[3.74, 5.03]	48.08	18.40	< .001*
	MWM + Tendon Vibration	2.46	1.63	[1.80, 3.12]	—	—	—
Baseline Grip Strength (kg)	HSR	19.04	3.24	[17.73, 20.35]	26.33	2.19	.145
	MWM + Tendon Vibration	20.46	3.68	[18.98, 21.95]	—	—	—
Post-Treatment Grip Strength (kg)	HSR	23.46	4.09	[21.81, 25.11]	286.23	21.37	< .001*
	MWM + Tendon Vibration	28.15	3.17	[26.87, 29.43]	—	—	—
Baseline PRTEE	HSR	54.65	7.85	[51.48, 57.82]	71.56	1.24	.271
	MWM + Tendon Vibration	52.31	7.35	[49.34, 55.28]	—	—	—
Post-Treatment PRTEE	HSR	20.38	4.01	[18.76, 22.00]	94.23	7.14	.010*
	MWM + Tendon Vibration	23.08	3.21	[21.78, 24.37]	—	—	—

Note. HSR = heavy slow resistance; MWM = mobilization with movement; NPRS = Numeric Pain Rating Scale; PRTEE = Patient-Rated Tennis Elbow Evaluation; M = mean; SD = standard deviation; CI = confidence interval. $p < .05$ was considered statistically significant. A lower NPRS indicates less pain, a higher grip-strength value indicates greater strength, and a lower PRTEE score indicates less pain and disability. Significant at $p < .05$.

Table 9 shows that the groups did not differ significantly at baseline for NPRS ($p = .656$), grip strength ($p = .145$), or PRTEE ($p = .271$), indicating comparable baseline measurements. After treatment, significant between-group differences were observed for NPRS ($p < .001$), grip strength ($p < .001$), and PRTEE ($p = .010$). The graphical representation of these findings is

presented in Figure 2. The MWM + tendon vibration group had lower post-treatment NPRS scores and higher grip strength, whereas the HSR group had a lower post-treatment PRTEE score. These findings demonstrate significant between-group differences in pain, grip strength, and functional disability following the intervention.

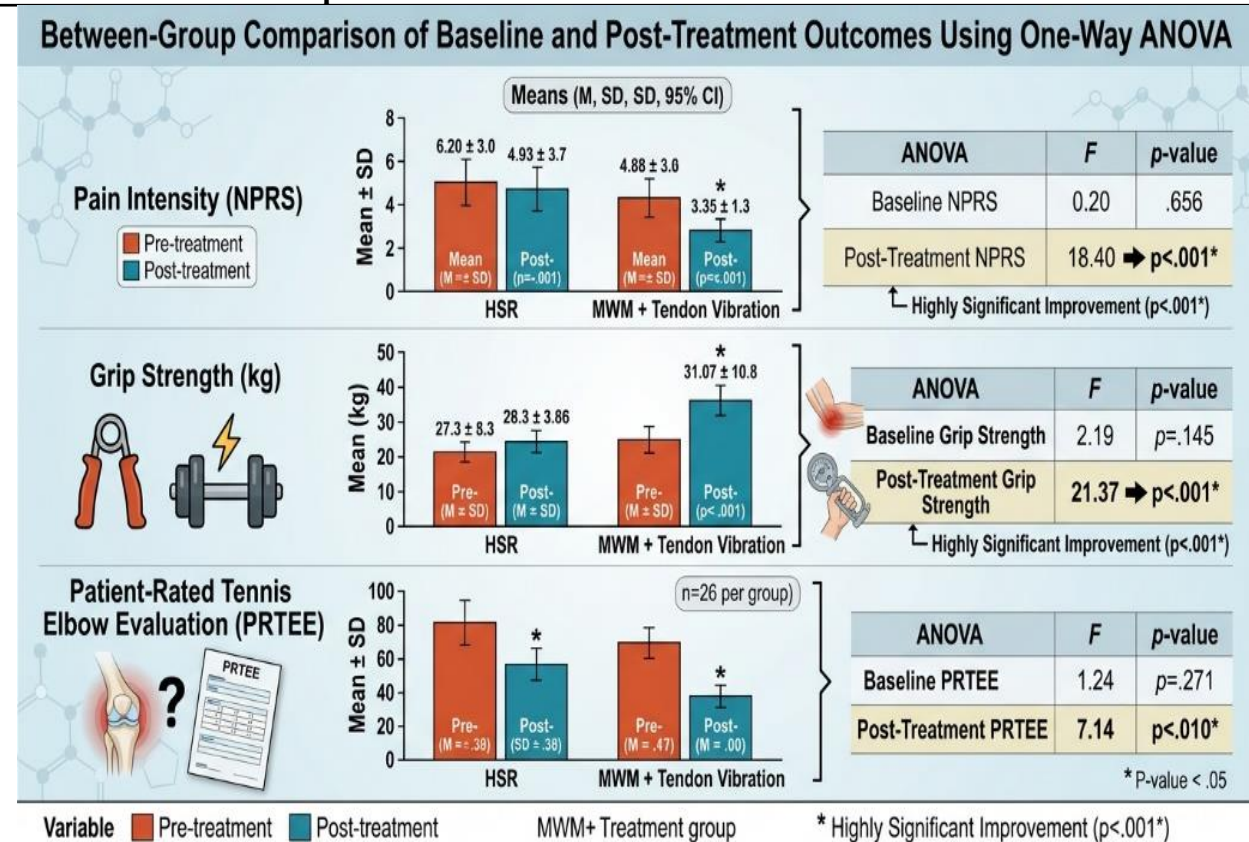


Figure 2 Between-Group Comparison of Baseline and Post-Treatment Outcomes Using One-Way ANOVA.

6 DISCUSSIONS

The present randomized controlled trial compared Heavy Slow Resistance (HSR) training with Mulligan Mobilization with Movement combined with Tendon Vibration (MWM + TV) for pain intensity, grip strength, and functional disability in athletes with lateral epicondylitis. Both interventions produced significant within-group improvements in NPRS, grip strength, and PRTEE scores following the four-week intervention ($p < .001$). At baseline, no statistically significant between-group differences were observed for NPRS, grip strength, or PRTEE, indicating comparable outcome status before treatment. These findings are consistent with the clinical characteristics of lateral epicondylitis, in which lateral elbow pain, impaired gripping capacity, and functional limitation are common outcomes used to evaluate treatment response [1–3].

Pain Intensity. Pain intensity decreased significantly in both groups. NPRS decreased from 6.81 ± 1.83 to 4.38 ± 1.60 in the HSR group and from 6.58 ± 1.88 to 2.46 ± 1.63 in the MWM + TV group. The between-group difference at post-treatment assessment was statistically significant ($p < .001$), with lower pain scores in the MWM + TV group. Previous studies have similarly reported beneficial effects of MWM on pain and clinical outcomes in lateral epicondylitis [12,18,20]. Reyhan et al. reported significant improvements following MWM, while Bagcaci et al. demonstrated improvements in pain and other clinical outcomes following MWM-based treatment [12,18]. Syed et al. also reported favourable effects of MWM combined with exercise in lateral elbow tendinopathy [20]. The greater reduction in pain observed with MWM + TV may be related to the application of an accessory radial-head glide during active

movement, potentially allowing previously painful movement to be performed with reduced symptoms. Tendon vibration may have provided additional sensory stimulation; however, because vibration was administered together with MWM, its independent contribution cannot be determined from the present findings.

Grip Strength. Grip strength increased significantly following both interventions. In the HSR group, grip strength increased from 19.38 ± 3.01 to 23.46 ± 4.09 kg, whereas the MWM + TV group improved from 21.01 ± 2.21 to 28.15 ± 3.17 kg. The post-treatment difference between groups was statistically significant ($p < .001$), with greater grip strength in the MWM + TV group. These findings are consistent with previous research demonstrating improvements in grip strength following MWM-based interventions [12,18,20]. Reduction in pain may partly explain the improvement in grip strength because pain can inhibit maximal force production during gripping. Previous research has also demonstrated the influence of pain and upper-extremity factors on pain-free grip strength in lateral elbow tendinopathy [8]. Nevertheless, the improvement observed in the HSR group is also clinically plausible because progressive resistance loading can improve muscular capacity and tolerance to tendon loading. Previous studies have reported favourable effects of resistance-based exercise and HSR approaches in lateral epicondylitis [14,16].

Functional Disability. PRTEE scores significantly decreased in both groups, indicating improvement in patient-reported pain and disability. The HSR group improved from 54.65 ± 7.85 to 20.38 ± 4.01 , whereas the MWM + TV group improved from 52.31 ± 7.35 to 23.08 ± 3.21 . The post-treatment between-group difference was statistically significant ($p = .010$), with a lower PRTEE score in the HSR group. Since lower PRTEE scores indicate less pain and disability, this finding suggests greater improvement in the patient-reported functional outcome with HSR. The result may be related to the progressive loading characteristics of HSR, which provide

repeated mechanical loading of the wrist and forearm musculotendinous structures and may improve strength and tolerance during functional activities. Previous evidence has supported resistance-based rehabilitation for lateral elbow tendinopathy [14,17,32]. At the same time, the improvement observed with MWM + TV is consistent with previous studies reporting beneficial effects of Mulligan-based mobilisation on pain, grip strength, and function [12,13,18].

Comparison of Interventions. The findings indicate that the treatment effects differed according to the outcome assessed. MWM + TV produced significantly lower post-treatment pain and greater grip strength, whereas HSR produced a significantly lower PRTEE score. Therefore, the findings do not demonstrate a single intervention as superior across all outcomes. The different response patterns may reflect the distinct therapeutic mechanisms of the interventions. MWM incorporates an accessory joint glide with active movement and may be particularly relevant to pain-modulated movement and grip performance, whereas HSR provides progressive resistance loading that may contribute to muscular capacity and functional tolerance. Previous literature has reported beneficial effects of both manual therapy and exercise-based approaches in lateral epicondylitis, although the magnitude of improvement may differ according to the outcome and intervention protocol [10–12,14,16–18,20]. Importantly, the present study evaluated MWM and tendon vibration as a combined intervention; therefore, the specific contribution of tendon vibration cannot be separated.

7 CONCLUSION

The present randomized controlled trial demonstrated significant improvements in pain, grip strength, and functional disability following four weeks of both Heavy Slow Resistance (HSR) and Mulligan Mobilisation with Movement combined with Tendon Vibration (MWM + TV) interventions in athletes with lateral epicondylitis. Significant between-group differences were observed after treatment for all three outcomes.

The MWM + TV group demonstrated lower post-treatment NPRS scores and greater grip strength, whereas the HSR group demonstrated lower post-treatment PRTEE scores. Thus, both interventions produced beneficial changes across the assessed outcomes, although the pattern of improvement differed according to the clinical outcome measured. Further studies involving larger samples, longer follow-up periods, and separate evaluation of tendon vibration are warranted to determine the durability of treatment effects and the specific contribution of each treatment component.

8 RECOMMENDATIONS

MWM combined with tendon vibration may be considered within rehabilitation programmes when pain reduction and improvement in grip strength are important treatment outcomes, while HSR training may be incorporated when progressive loading and improvement in patient-reported functional disability are treatment priorities. Future clinical trials should compare MWM alone with MWM combined with tendon vibration to determine the independent contribution of tendon vibration [34]. Larger multicentre studies with longer follow-up periods are also recommended to evaluate the sustainability of treatment effects. Future research should additionally consider outcomes such as return to sport, work-related function, quality of life, and long-term disability. Comparative studies investigating combined manual therapy and progressive resistance protocols may further clarify the role of multimodal rehabilitation approaches in patients with lateral epicondylitis.

9 LIMITATIONS

The study had several limitations. First, the sample size was relatively small, comprising 52 participants, which may limit the generalisability of the findings to broader populations with lateral epicondylitis. Second, the intervention period was limited to four weeks; therefore, the persistence of treatment effects beyond the intervention period could not be determined. Third, tendon vibration was administered in combination with MWM,

preventing assessment of its independent therapeutic contribution [35]. Fourth, the study primarily assessed NPRS, grip strength, and PRTEE and did not evaluate longer-term outcomes such as return to sport, work-related disability, quality of life, or psychological factors. Finally, participants were recruited from a single clinical setting and consisted of athletes aged 20–40 years; therefore, the findings should be interpreted within the characteristics of the study population and clinical setting.

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