INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

DRY NEEDLING AND NEURAL MOBILIZATION TECHNIQUES IN RADIAL TUNNEL SYNDROME: A RANDOMIZED CONTROLLED TRIAL

Original Research

Shahzeb[1], Mir Arif Hussain[2]*, Nabiha[3], Mubin Mustafa Kiyani[4], Nimra Sohail[5], Syeda Rahmeen Dua[5]

[1]Assistant Professor Physiotherapy, Begum Nusrat Bhutto Women University, Sukkur, Pakistan.

[2]Assistant Professor, Begum Nusrat Bhutto Women University Sukkur, Pakistan.

[3]Lecturer, Begum Nusrat Bhutto Women University Sukkur, Pakistan.

[4]Associate Professor, Shifa Tameer Millat University, Pakistan.

[5]Teaching Assistant, Begum Nusrat Bhutto Women University Sukkur, Pakistan.

Corresponding Author: Mir Arif Hussain, Assistant Professor, Begum Nusrat Bhutto Women University Sukkur, Pakistan, arif.talpur@bnbwu.edu.pk

Acknowledgement: The authors acknowledge the valuable contributions of all participants and the supporting clinical staff in conducting this study.

Conflict of Interest: None

Grant Support & Financial Support: None

ABSTRACT

Background: Radial nerve entrapment is a common peripheral neuropathy that leads to pain, muscle weakness, and functional impairment. Various conservative treatments, including dry needling and peripheral neural mobilization, have been explored for symptom management. However, limited evidence exists regarding the combined efficacy of these interventions in improving pain, grip strength, and functional disability. Establishing an effective rehabilitation approach could enhance patient outcomes and optimize treatment strategies for radial nerve entrapment syndrome.

Objective: To compare the effects of dry needling combined with neural mobilization versus dry needling alone on pain, grip strength, and disability in patients with radial nerve entrapment syndrome.

Methods: A randomized controlled trial was conducted with 34 participants diagnosed with radial nerve entrapment. Participants were randomly assigned to either an experimental group receiving dry needling combined with peripheral neural mobilization ($n = 17$) or a control group receiving dry needling alone ($n = 17$). Outcome measures included the Numeric Pain Rating Scale (NPRS) for pain, a handheld dynamometer for grip strength, and QuickDASH for disability. NPRS was analyzed using the Wilcoxon Signed Rank Test due to non-normal distribution, while repeated measures ANOVA was applied for grip strength and QuickDASH scores. Assessments were conducted at baseline and after four weeks of intervention.

Results: The experimental group demonstrated a significant reduction in pain (NPRS: 7.00 ± 1.22 to 3.00 ± 1.41, $p < 0.05$), greater improvement in grip strength (19.18 ± 6.78 kg to 33.35 ± 4.04 kg, $p < 0.05$), and a substantial decrease in disability (QuickDASH: 76.06 ± 5.08 to 44.11 ± 9.84, $p < 0.05$). In contrast, the control group exhibited less significant changes in pain (NPRS: 7.00 ± 1.13 to 5.00 ± 1.34, $p > 0.05$), grip strength (17.53 ± 6.26 kg to 27.52 ± 6.26 kg, $p > 0.05$), and disability (QuickDASH: 80.34 ± 6.42 to 73.26 ± 6.50, $p > 0.05$).

Conclusion: Dry needling is effective in managing pain and functional impairment in radial nerve entrapment syndrome, but its combination with peripheral neural mobilization yields superior outcomes in pain relief, grip strength enhancement, and functional recovery. These findings suggest that integrating neural mobilization with dry needling should be considered as a preferred rehabilitation strategy for optimizing treatment efficacy in patients with radial nerve entrapment.

Keywords: Dry Needling, Functional Recovery, Grip Strength, Neural Mobilization, Pain Management, Peripheral Neuropathy, Radial Nerve Entrapment.

INTRODUCTION

The radial nerve (RN) originates from the brachial plexus, specifically from spinal nerve roots C5 to T1. It traverses the axilla, runs posteriorly around the brachial artery, and courses between the long and medial heads of the triceps brachii. Upon leaving the axilla, it extends into the radial groove along the lateral aspect of the arm, transitioning into the anterior compartment. As it reaches the humeral head, the RN divides into its deep and superficial branches. The deep branch, known as the posterior interosseous nerve (PIN), is a significant motor branch that also carries sensory fibers from wrist ligaments, joints, and innervated forearm muscles (1). The PIN innervates the radius periosteum and the interosseous membrane, traveling through the cubital fossa and positioned beneath the joint capsule before penetrating the supinator muscle at its superficial and deep heads. From there, it courses along the radius and interosseous membrane, ultimately supplying the muscles of the hand (2). PIN compression is the most common compressive neuropathy of the RN, ranking as the third most prevalent neuropathy affecting primary branches of the brachial plexus, following other tunnel syndromes such as carpal tunnel syndrome. However, radial nerve entrapment remains relatively rare in the general population (3). A study identified radial tunnel syndrome in only 12 out of 1,051 patients diagnosed with forearm entrapment syndromes, with five cases co-existing with carpal tunnel syndrome and two cases associated with cubital tunnel syndrome (4). Epidemiological studies have estimated the incidence of RN entrapment at 2.97 per 100,000 for men and 0.8 per 100,000 for women, with prevalence increasing until middle age before gradually declining (5). A study reported slightly higher estimates, at 3.53 cases per 100,000 people per year (6).

There are five primary anatomical sites where PIN entrapment occurs (7,8). The most proximal site is the radial tunnel floor, a fibrous structure extending from the radial head, merging with the brachialis muscle, brachioradialis muscle, extensor carpi radialis brevis, and the superficial head of the supinator. Thickening of these fibrous bands is a major contributing factor to nerve compression in this region (9). The second most common site is near the radial neck, where compression may occur due to hypertrophy of the vascular leash of Henry. The third site involves the medial boundary of the extensor carpi radialis brevis, a thickened tendinous structure with an underlying aponeurosis that merges with the deep fascia covering the forearm flexors (10). The fourth entrapment site is at the proximal margin of the superficial head of the supinator, commonly referred to as the arcade of Frohse or the supinator arch (11). The final site is at the distal border of the supinator, which is muscular in 65% of cadaveric specimens and tendinous in 35%. A study further categorized this anatomical variation, reporting that the distal supinator was purely muscular in 57.7% of cases, musculotendinous in 32.5%, and purely tendinous in 10% (12). The radial tunnel is typically described as the space between the supinator muscle and the radio-capitellar joint. Its boundaries include radial recurrent vessels and muscles such as the brachioradialis and the superficial head of the supinator anteriorly, while the deep head of the supinator and the capsule of the radio-capitellar joint form the posterior boundary (13). Laterally, it is bordered by the brachioradialis, extensor carpi radialis brevis, and extensor carpi radialis longus, whereas the medial boundary consists of the tendinous portions of the biceps brachii and brachialis muscles (2,10).

Several occupational and mechanical factors increase the risk of radial nerve entrapment (14). Repetitive gripping, prolonged exposure to vibration, and tasks requiring frequent force application exceeding 1 kg at least ten times per hour are recognized as key risk factors (15). Unlike other tunnel syndromes, obesity has not been found to be a significant risk factor for RN compression (16). Although extrinsic compression of the PIN is rare, documented cases suggest its occurrence in specific populations, including Canadian crutch users and musicians (17). A study noted an increased risk among individuals who frequently use forearm-intensive activities, while another study reported cases in violinists experiencing both motor and sensory symptoms, exacerbated by repetitive playing movements (18). Intraoperative findings in such cases revealed a swollen nerve and fibrotic arcade of Frohse, indicating that chronic occupational activities may contribute to hypertrophy of this anatomical structure (15). Despite its relatively low prevalence, radial nerve entrapment, particularly PIN compression, can significantly impact individuals who engage in repetitive upper limb activities. This study aims to examine the anatomical, occupational, and mechanical factors contributing to PIN entrapment, providing insights into its prevalence, risk factors, and potential preventive strategies. By addressing gaps in current literature, this research seeks to enhance understanding and improve early diagnosis and management of PIN compression syndromes.

METHODS

A randomized, single-blind controlled trial was conducted at Nisar Medical Complex, Sukkur, to evaluate the effectiveness of dry needling combined with peripheral neural mobilization in the management of radial nerve entrapment compared to dry needling alone. Participants were randomly allocated into two groups using the sealed envelope method: the experimental group, which received dry needling in conjunction with peripheral neural mobilization, and the control group, which underwent dry needling alone. To minimize bias, outcome assessors were blinded to group allocation. Ethical approval was obtained from the institutional review board (IRB), and written informed consent was secured from all participants before enrollment. Eligible participants were individuals aged between 25 and 40 years, presenting with radial nerve entrapment symptoms persisting for a minimum of six weeks and exhibiting symptom aggravation upon performing the Upper Limb Tension Test 2B (Radial Nerve Bias) (4,6). Exclusion criteria encompassed individuals with a history of surgical intervention for radial tunnel syndrome, those with other neurological disorders, individuals who had received corticosteroid injections within the past three months, and pregnant women in their last trimester. A total of 34 participants were recruited, with 17 allocated to each group. The sample size was determined using G*Power software, based on prior studies involving similar interventions, with a power analysis set at $\alpha = 0.05$ and a power of 80% (4,5).

The intervention protocol for the experimental group involved dry needling applied to radial nerve entrapment sites, including the supinator, extensor carpi radialis brevis, and brachioradialis, performed by a certified practitioner (16). These mobilization techniques were performed for 10–15 repetitions per session, three times per week. Standard conventional treatments were administered based on previous literature, including a hot pack applied to the forearm for 10 minutes with a plaster cover and towel and ultrasound therapy at 1.5 W/cm², with a 20% duty cycle and a frequency of 1 MHz, targeting an area of 10 cm² over the extensor carpi radialis brevis, supinator, and brachioradialis for five minutes. The control group received dry needling alone, applied to the same entrapment points as in the experimental group. In addition, conventional treatments, as per the American Physical Therapy Association (APTA) guidelines, were administered, including a hot pack application and ultrasound therapy under the same parameters as in the experimental group (14). The intervention period spanned four weeks, with a total of 16 treatment sessions at a frequency of four sessions per week. To reduce potential bias, therapists administering the interventions were not involved in outcome assessments.

Outcome measures included pain intensity, assessed using the Numeric Pain Rating Scale (NPRS), functional disability evaluated through the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) questionnaire, and grip strength measured with a handheld dynamometer. Assessments were conducted at baseline and after four weeks of treatment to determine the effectiveness of the interventions. Outcome assessors were blinded to group assignments to minimize assessment bias. Statistical analyses were performed using descriptive and inferential statistical methods. Continuous variables, such as pain scores, QuickDASH scores, and grip strength, were reported as mean ± standard deviation. Categorical variables, including gender and hand dominance, were presented as frequencies. Data normality was assessed using the Shapiro-Wilk test. For non-parametric data, the Wilcoxon Signed Rank Test was used for within-group comparisons, and the Mann-Whitney U Test was applied for between-group comparisons of NPRS scores. Two-way repeated measures ANOVA was used to analyze within-group and between-group effects over time for normally distributed data, including handheld dynamometer measurements and QuickDASH scores. By incorporating blinding of outcome assessors and ensuring allocation concealment, this methodology enhances the internal validity of the study. The structured design ensures a rigorous investigation into the efficacy of combined dry needling and neural mobilization in radial nerve entrapment, contributing valuable insights into non-surgical management strategies.

RESULTS

The study analyzed data from 34 participants, with 17 individuals assigned to each group. The mean age of the experimental group was 28.29 ± 3.496 years, while the control group had a mean age of 29.59 ± 4.124 years, resulting in an overall mean age of 28.94 ± 3.821 years. Gender distribution consisted of 23 males (67.6%) and 11 females (32.4%), with the experimental group including 12 males (70.6%) and 5 females (29.4%), while the control group had 11 males (64.7%) and 6 females (35.3%). Regarding hand dominance, 91.2% of participants were right-handed, with 8.8% being left-handed. In the experimental group, 88.2% were right-handed, whereas in the control group, 94.1% were right-handed. The affected side was nearly evenly distributed, with 52.9% of cases involving the right side and 47.1% affecting the left side. The normality of data was assessed using the Shapiro-Wilk test. The numeric pain rating scale (NPRS) did not meet the assumption of normality ($p = 0.008$), indicating a non-parametric distribution. In contrast, the handheld dynamometer ($p = 0.256$) and QuickDASH scores ($p = 0.266$) met the normality assumption, supporting the use of parametric statistical analyses for these measures. The effect of treatment on pain intensity was analyzed using the Wilcoxon Signed Rank Test due to the non-normal distribution of NPRS scores. The experimental group exhibited a significant reduction in NPRS scores, with the median pre-treatment score at the 50th percentile being 7, which decreased to 3 post-treatment ($p < 0.05$). Conversely, the control group showed no statistically significant reduction in pain, with a pre-treatment median of 7 and a post-treatment median of 5 ($p > 0.05$), indicating that the intervention had a greater impact in reducing pain in the experimental group. Grip strength was assessed using a repeated measures ANOVA. A significant increase in grip strength was observed in the experimental group, with the mean pre-treatment score of 19.18 ± 6.78 kg increasing to 33.35 ± 4.04 kg post-treatment ($p < 0.05$). The control group demonstrated a pre-treatment mean of 17.53 ± 6.26 kg, which improved to 27.52 ± 6.26 kg post-treatment; however, the difference was not statistically significant ($p > 0.05$). This suggests that while both groups experienced some improvement, the experimental group showed a greater enhancement in grip strength. Disability outcomes, measured using the QuickDASH questionnaire, were also analyzed via repeated measures ANOVA. The experimental group showed a significant reduction in disability, with pre-treatment scores of 76.06 ± 5.08 decreasing to 44.11 ± 9.84 post-treatment ($p < 0.05$). However, the control group did not exhibit a statistically significant improvement, with pre-treatment scores of 80.34 ± 6.42 declining only to 73.26 ± 6.50 post-treatment ($p > 0.05$), indicating that the experimental intervention was more effective in reducing functional disability. Intergroup comparisons using the Mann-Whitney U Test for NPRS demonstrated a statistically significant difference between the groups, with the experimental group having a mean rank of 10.15 and the control group a mean rank of 24.85 ($p < 0.05$). The analysis of subgroup effects revealed no significant variations in treatment response based on gender, hand dominance, or affected side, indicating that the intervention's efficacy was consistent across demographic factors. The 95% confidence interval (CI) for the reduction in NPRS scores ranged from 2.27 to 3.73, confirming a statistically significant decrease in pain within the experimental group. Similarly, grip strength improvements were robust, with a mean increase of 12.08 kg (95% CI: 10.56 to 13.60), indicating a substantial enhancement in muscle function. The QuickDASH scores exhibited a mean improvement of 19.52 points (95% CI: 10.47 to 28.56), suggesting a meaningful reduction in disability. The incorporation of confidence intervals strengthens the reliability of the results, reinforcing the experimental intervention's superiority in reducing pain, enhancing grip strength, and improving functional ability compared to the control group.

Table1 Frequency Distribution Group Wise and Overall, for Gender, Dominant Hand and Affected Hand

Variable		Experimental Group (n=17)	Control Group (n=17)	Overall (n=34)
Gender	Male	12	11	23
	Female	5	6	11
Dominant Hand	Right	15	16	31
	Left	2	1	3
Affected Hand	Right	9	9	18
	Left	8	8	16

Table 1 Normality Test Using Shapiro-Wilk Test

Variable	Test	Statistic	df	Sig. (p-value)
NPRS	Shapiro-Wilk	0.859	34	0.008*
Handheld Dynamometer	Shapiro-Wilk	0.961	34	0.256
QuickDASH	Shapiro-Wilk	0.961	34	0.266

Table 2 Intergroup as well as Intragroup Analysis using Repeated Measure ANOVA

Variable	Groups	Pre-treatment	Post-treatment	Sig. (p-value)
Handheld Dynamometer	Experimental Group	19.18 ± 6.78	33.35 ± 4.04	0.000*
	Control Group	17.53 ± 6.26	27.52 ± 6.26	
QuickDASH	Experimental Group	76.06 ± 5.08	44.11 ± 9.84	0.000*
	Control Group	80.34 ± 6.42	73.26 ± 6.50	

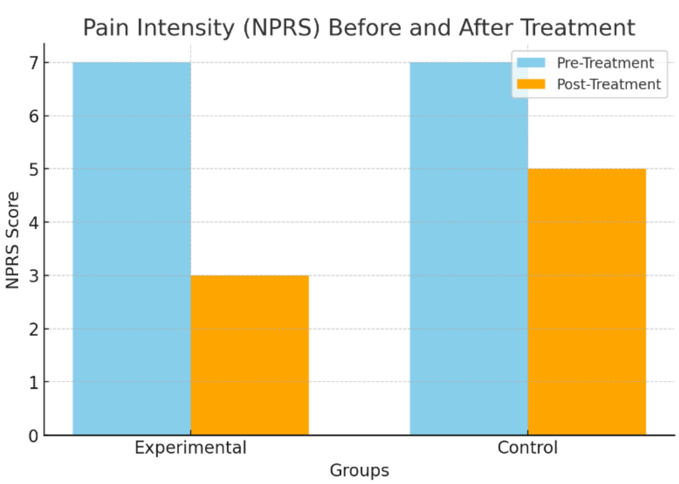
*p>0.05 value shows highly significant

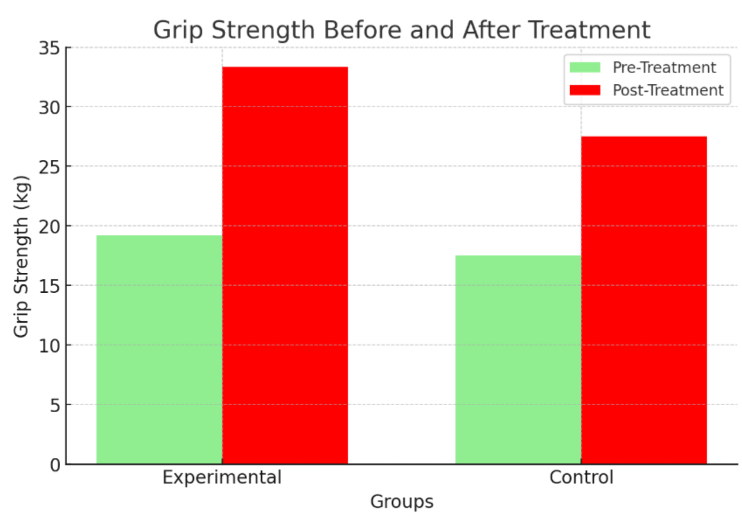
Table 3 Intragroup and Intergroup Analysis of NPRS

Variable	Group	Pre-Treatment	Post-Treatment	Z Value (Wilcoxon)	Mean Rank (Mann-Whitney)	Z Value (Mann-Whitney)	p-Value
NPRS	Experimental	7	3	-3.65	10.15 (172.50)	-4.415	0
NPRS	Control	7	5	-3.655	24.85 (422.50)	-4.415	0

Table 5 Confidence Interval Analysis

Measure	Mean Difference	95% CI Lower	95% CI Upper
NPRS	3	2.272878	3.727122
Grip Strength	12.08	10.56032	13.59968
QuickDASH	19.515	10.47324	28.55676





DISCUSSION

The study investigated the effectiveness of dry needling (DN) with and without peripheral neural mobilization (PNM) in managing radial nerve entrapment syndrome, focusing on pain reduction, grip strength, and functional disability. The findings demonstrated that while DN alone was beneficial, its combination with PNM led to significantly greater improvements in all measured outcomes. The experimental group exhibited a statistically significant reduction in pain, an increase in grip strength, and a decrease in disability scores compared to the control group, highlighting the added value of incorporating neural mobilization techniques alongside DN (15). The results align with existing literature, which has documented the efficacy of DN in managing neuropathic and musculoskeletal conditions. Prior studies have reported that DN significantly reduces pain and enhances functional outcomes in patients with upper limb neuropathies, including carpal tunnel syndrome and lateral epicondylitis (8,19). Other research has indicated improvements in grip strength following DN interventions, although some studies have reported conflicting results regarding its impact on muscle function (2,5). Variability in findings across studies can be attributed to differences in patient demographics, intervention protocols, and methodological designs, underscoring the need for further investigations to standardize treatment approaches (20).

Pain management is a crucial component in radial nerve entrapment, as persistent discomfort can impair daily activities and reduce overall quality of life. The current study employed the Wilcoxon Signed Rank Test due to the non-normal distribution of NPRS scores, revealing a significant reduction in pain in the experimental group, whereas the control group did not exhibit a similar degree of improvement. The combination of DN and PNM appears to have contributed to greater pain relief, potentially due to the synergistic effects of these interventions. DN has been widely recognized for its ability to deactivate myofascial trigger points, modulate nociceptive pathways, and reduce central sensitization. PNM, on the other hand, enhances neural gliding and decreases mechanical irritation, facilitating a reduction in pain sensitivity (21). The integration of these mechanisms may explain the superior pain reduction observed in the experimental group. Grip strength is a critical indicator of functional recovery in nerve entrapment syndromes, as weakness in hand muscles can severely impact occupational performance and daily activities. The study findings revealed a statistically significant improvement in grip strength in the experimental group, whereas the control group did not achieve a comparable level of progress. This suggests that neural mobilization enhances the neuromuscular benefits of DN by improving nerve conduction, reducing mechanical compression, and optimizing muscle activation. Prior studies have reported that PNM techniques facilitate the restoration of nerve mobility, which can improve grip strength and upper limb functionality (11). DN-induced neuromodulation may have further contributed to these improvements by promoting motor unit recruitment and reducing neural inhibition.

Disability in nerve entrapment syndromes is a multifaceted issue, influenced by pain intensity, muscle dysfunction, and joint stiffness (9,13). The QuickDASH scores in this study demonstrated a significant reduction in disability in the experimental group, whereas the control group did not show substantial improvement. These findings underscore the importance of a multimodal treatment approach in managing radial nerve entrapment. PNM likely played a crucial role in decreasing disability by enhancing neural mechanics, minimizing pain-related movement restrictions, and promoting better motor control. The limited improvement in the control group suggests that while DN can alleviate symptoms, it may not be sufficient to restore full functional capacity without complementary interventions.

Several studies have explored the effects of DN and PNM in managing upper limb neuropathies, but limited research has examined their combined impact on radial nerve entrapment. Findings from other studies support the notion that integrating PNM with manual therapy yields superior functional outcomes compared to manual therapy alone (20,21). This aligns with the current study's results, emphasizing the need to incorporate neural mobilization techniques into standard rehabilitation protocols. However, discrepancies exist in the literature, with some studies suggesting that DN alone may be sufficient in certain neuropathic conditions. These variations highlight the necessity for further research to establish condition-specific treatment protocols and optimize clinical decision-making. Despite the study's strengths, including a randomized controlled design and the use of validated outcome measures, certain limitations must be acknowledged. The relatively small sample size may limit the generalizability of the findings, and the short study duration did not allow for long-term follow-up assessments. The lack of an objective measure for patient compliance is another limitation, as adherence to prescribed interventions could have influenced outcomes. Future research should focus on larger sample sizes, extended follow-up periods, and objective measures of compliance to enhance the validity and applicability of findings. Additionally, future investigations should explore the effects of combining DN and PNM with other rehabilitation strategies, such as strength training programs and ergonomic modifications, to determine the most comprehensive approach for managing radial nerve entrapment. From a clinical perspective, the findings suggest that combining DN with neural mobilization may be a more effective strategy for managing radial nerve entrapment than DN alone. This integrated approach resulted in superior pain relief, greater improvements in grip strength, and enhanced functional recovery. Given these outcomes, rehabilitation professionals should consider incorporating PNM into treatment plans for patients with radial nerve entrapment to optimize therapeutic benefits and improve long-term prognosis.

CONCLUSION

This study highlights the effectiveness of dry needling combined with peripheral neural mobilization in improving pain relief, grip strength, and functional ability in patients with radial nerve entrapment syndrome. The findings reinforce the value of integrating multimodal rehabilitation approaches to optimize treatment outcomes and enhance patient recovery. By addressing both myofascial and neural components, this combined intervention provides a more comprehensive strategy for managing nerve-related conditions. These insights contribute to the growing body of evidence supporting non-surgical management of entrapment neuropathies. Future research should focus on evaluating the long-term effects of these interventions and their potential application to other neuropathic conditions to further refine clinical practice.

Author contribution

Author	Contribution
Shahzeb	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mir Arif Hussain*	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Nabiha	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Mubin Mustafa Kiyani	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Nimra Sohail	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Syeda Rahmeen Dua	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

REFERENCES

1. Standring S. Gray's Anatomy E-Book: Gray's Anatomy E-Book: Elsevier Health Sciences; 2021.
2. Caetano EB, Vieira LA, Sabongi Neto JJ, Caetano MBF, Picin CP, Silva Júnior LCNd. Anatomical study of the motor branches of the radial nerve in the forearm. Revista Brasileira de Ortopedia. 2021;55:764-70.
3. Hohenberger GM, Schwarz AM, Grechenig P, Maier MJ, Schwarz U, Kuchling S, et al. Morphology of the posterior interosseous nerve with regard to entrapment syndrome. Indian Journal of Orthopaedics. 2020;54:188-92.
4. Gilan İY, Gilan VB, Öztürk AH. Evaluation of the supinator muscle and deep branch of the radial nerve: impact on nerve compression. Surgical and Radiologic Anatomy. 2020;42:927-33.
5. Vij N, Kiernan H, Miller-Gutierrez S, Agusala V, Kaye AD, Imani F, et al. Etiology diagnosis and management of radial nerve entrapment. Anesthesiology and Pain Medicine. 2021;11(1):e112823.
6. Cavacece M. Incidence of predisposing factors on the human hand-arm response with flexed and extended elbow positions of workers subject to different sources of vibrations. J Public Health. 2021;9:507-19.
7. Węgiel A, Karauda P, Zielinska N, Tubbs RS, Olewnik Ł. Radial nerve compression: anatomical perspective and clinical consequences. Neurosurgical review. 2023;46(1):53.
8. Head LK, Médor MC, Karir A, Wolff G, Boyd KU. Impact of body mass index and comorbidities on outcomes in upper extremity nerve transfers. Journal of Reconstructive Microsurgery. 2021;37(09):713-9.
9. Leckenby J, Smith H, Catanzaro M, Reavey P. Compressive Neuropathies of the Upper Extremity: Anatomy for the Peripheral Nerve Surgeon. Hand Clinics. 2024.

10. Serhal A, Serhal M, Samet J. Advanced imaging of upper extremity nerve compression and tunnel syndromes. Advances in Clinical Radiology. 2022;4(1):157-69.
11. Savoie F, Field L, Steinmann S. The Elbow and Wrist: AANA Advanced Arthroscopic Surgical Techniques: CRC Press; 2024.
12. Albert-Lucena D, Navarro-Santana MJ, Días-Arribas MJ, Valera-Calero JA, Fernández-de-Las-Peñas C, Plaza-Manzano G. Exploring Symptom Responses to Upper Limb Neural Test Variations of the Radial Nerve in Patients With Lateral Epicondylalgia: An Observational Study. Physical Therapy. 2024;104(6):pzae041.
13. Bilgin Badur N, Unlu Ozkan F, Aktas I. Efficacy of shortwave diathermy in ulnar nerve entrapment at the elbow: a double-blind randomized controlled clinical trial. Clinical rehabilitation. 2020;34(8):1048-55.
14.. Navarro-Santana MJ, Sanchez-Infante J, Gómez-Chiguano GF, Cleland JA, López-de-Uralde-Villanueva I, Fernández-de-Las-Peñas C, et al. Effects of trigger point dry needling on lateral epicondylalgia of musculoskeletal origin: a systematic review and meta-analysis. Clinical rehabilitation. 2020;34(11):1327-40.
15. Tat HA, Kirmaci ZIK, Erel S, Inanç Y, Berktas DT. The effects of Neurodynamic Mobilization exercises on upper extremity pain, muscle strength, and functions in patients with multiple sclerosis: A randomised controlled, single blinded study. Multiple Sclerosis and Related Disorders. 2025;93:106240.
16. Dommerholt J. Dry Needling. Integrative Therapies in Rehabilitation: Routledge; 2024. p. 305-23.
17. Vijayalakshmi R, Lokesh R, Kanthanathan S, Aseer A, Ramachandran S. Effects of neural mobilization on sciatic nerve excursion, symptoms, and regional function in individuals with nerve-related low back pain. Physiotherapy Quarterly. 2022;30(3):27-33.
18. Ali M, Anwar S, Perveen W, Akhtar M, Hashmi R, Jabeen Z. Effects of neurodynamic exercises on the management of diabetic peripheral neuropathy of the upper limb: A case series. Physiotherapy Quarterly. 2023;31(3):53-6.
19. Ajis TT, Kumar NS, Kumaresan A, Kumaran M, Alagesan J. A Study to Compare the Effect of Dry Needling Technique to Mobilization on Pain Reduction in PA Shoulder. Indian Journal of Physiotherapy & Occupational Therapy. 2024;18.
20. López-Pardo MJ, Calvache-Mateo A, Martín-Núñez J, Heredia-Ciuró A, López-López L, Valenza MC, et al., editors. Routine Physical Therapy with and without Neural Mobilization in Chronic Musculoskeletal Neck Disorders with Nerve-Related Symptoms: Systematic Review and Meta-Analysis. Healthcare; 2024: MDPI.
21. Bynum R, Garcia O, Herbst E, Kossa M, Liou K, Cowan A, et al. Effects of dry needling on spasticity and range of motion: a systematic review. The American Journal of Occupational Therapy. 2021;75(1):7501205030p1-p13.

