

Effect of laser therapy along with hand strengthening exercises on nerve conduction and hand function in patients of carpal tunnel syndrome with rheumatoid arthritis

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Article History

Received: 18.01.2025
Accepted: 24.02.2025
Published: 11.03.2025

Abstract:

Background: Carpal tunnel syndrome (CTS) is a common neurological disorder, particularly in individuals with rheumatoid arthritis (RA). Laser therapy combined with strengthening exercises has been proposed as an effective treatment strategy to alleviate symptoms and improve function in CTS patients with RA. The aim of study was to evaluate the efficacy of laser therapy combined with strengthening exercises in comparison to strengthening exercises alone in reducing pain, improving functional status, alleviating symptoms, improving grip strength and enhancing nerve conduction parameters in CTS patients with RA.

Methods: A total of 37 participants were enrolled in study and 30 subjects were successfully completed, subjects were randomly assigned to the experimental group (EG; n=15) receiving laser therapy with strengthening exercises, or the control group (CG; n=15) receiving strengthening exercises alone. Outcome measures included pain intensity (NPRS), symptom severity (BCTQ-SSS), functional status (BCTQ-FSS), disease activity (DAS28), grip strength (Jamar dynamometer), and nerve conduction parameters (SCV, MCV, DML). Assessments were performed at baseline, 2 weeks, and 6 weeks.

Results: Within-group analysis showed significant improvements in pain intensity (EG: 64.94%, CG: 27.58%), symptom severity (EG: 45.36%, CG: 14.16%), functional status (EG: 43.66%, CG: 12.57%), and disease activity (EG: 27.09%, CG: 8.46%) in both groups. However, between-group analysis demonstrated statistically significant improvements favoring the experimental group in pain intensity (p=0.026), symptom severity (p=0.001), functional status (p=0.018), disease activity (p=0.017), and sensory conduction velocity (p=0.048) at 6 weeks. No significant between-group differences were found in grip strength (p=0.179), motor conduction velocity (p=0.064) and distal motor latency (p=0.103).

Conclusion: The findings suggest that laser therapy combined with strengthening exercises is more effective than strengthening exercises alone in reducing pain, improving functional status, reducing disease activity and enhancing sensory nerve conduction in CTS patients with RA. This highlights the potential of laser therapy as an adjunctive treatment in managing CTS symptoms in RA patients.

Keywords: Carpal Tunnel Syndrome, Rheumatoid Arthritis, Laser Therapy, Strengthening Exercises, Pain Management, Functional Status, Nerve Conduction.

Cite this article:

Mohammad, Z., Choudhry, D., Garg, A., Ekta, Malika., (2025). Effect of laser therapy along with hand strengthening exercises on nerve conduction and hand function in patients of carpal tunnel syndrome with rheumatoid arthritis. *ISAR Journal of Multidisciplinary Research and Studies*, 3(3), 18-24.

Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy, characterized by the compression of the median nerve at the wrist within the carpal tunnel.¹ It is a mechanically induced mononeuropathy caused by increased pressure within the tunnel, leading to nerve dysfunction.² The carpal tunnel is a fibro-osseous passage formed by carpal bones and the flexor retinaculum, through which the median nerve and nine flexor tendons pass.² Among all neurological complications associated with rheumatoid arthritis (RA), CTS is the most prevalent, with a higher incidence in women than men at a ratio of 3:1.³ The prevalence of CTS in RA patients ranges from 3.5% to 22.8%, with an estimated 10.1% prevalence in the Indian population.⁴

The clinical presentation of CTS includes tingling, numbness, and pain in the median nerve distribution, often worsening at night or during wrist flexion activities.⁵ Symptoms progress through three stages: early-stage paresthesia and nocturnal numbness, mid-stage persistent symptoms with activity-induced discomfort, and late-stage thenar muscle atrophy with functional impairment.⁶ Rheumatoid arthritis further exacerbates CTS symptoms due to synovial inflammation, tenosynovitis, and increased intra-carpal tunnel pressure, leading to nerve compression.⁷ Unlike idiopathic CTS, RA-related CTS primarily results from synovial proliferation, joint erosions, and pannus formation, reducing carpal tunnel space and increasing mechanical stress on the median nerve.⁸

Risk factors for CTS include repetitive wrist motion, obesity, diabetes mellitus, hypothyroidism, pregnancy, osteoarthritis, acromegaly, chronic renal insufficiency, and inflammatory conditions like RA.⁹ The American Academy of Orthopaedic Surgeons (AAOS) defines CTS as a symptomatic compression neuropathy of the median nerve at the wrist, diagnosed through clinical tests such as Tinel's sign, Phalen's maneuver, and nerve conduction studies.¹⁰ Conservative management options include rest, splinting, nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections, and physiotherapeutic interventions such as ultrasound therapy, iontophoresis, and laser therapy.¹¹ If conservative treatments fail, surgical decompression is recommended.¹²

Low-level laser therapy (LLLT), also known as photobiomodulation, has emerged as a non-invasive modality for managing CTS.¹³ Laser therapy has been shown to reduce pain, inflammation, and synovitis while promoting tissue repair and nerve regeneration.¹⁴ It stimulates cellular activity by enhancing ATP production, DNA synthesis, cell proliferation, and protein synthesis.¹⁵ Additionally, hand and wrist strengthening exercises improve dexterity and functionality, potentially enhancing the effects of laser therapy in CTS management.¹⁶

Materials and Methods

The ethical clearance was taken from the institutional biomedical research ethical committee of Pandit Bhagwat Dayal Sharma University of Health Sciences, Rohtak, with reference letter No. BREC/23/TH-Physiotherapy/38, dated 20/07/2023 and was also registered at Clinical Trials Registry- India (CTRI) as CTRI/2024/02/063120. A total of 37 subjects were enrolled in the study as per inclusion and exclusion criteria after signing the consent form. Out of enrolled 37 subjects, 7 subjects were

excluded because 2 went for surgery (EG), 2 didn't completed the whole treatment protocol (1 EG, 1 CG) and 3 didn't come for follow back (CG). Subjects were randomly divided among two groups by using lottery method into Group A (experimental group, who received hand strengthening exercises with the help of therapeutic putty (85g) and was provided laser therapy using Ga-As laser diode (Electronica Pagani, Mod: HPL 1.6, Made in Italy) with IR source 808 nm and effective power 1200 mW. Laser therapy dose was given 320 joules/cm² per session. The probe of laser was applied with direct contact perpendicularly on 5 points over the median nerve course where it passes superficially on the wrist volar side.^{2, 17, 18}) and Group B (control group, who received only hand strengthening program with the help of therapeutic putty (85g)). The Laser protocol was performed five times a week for 2 weeks at college of physiotherapy, Pt. BDS PGIMS, Rohtak and 4 weeks home care exercise program which include hand strengthening exercise was followed by all patients of both the groups. Patients were advised to bring the used therapeutic putty to the follow-up session in order to examine the exercise adherence of the individuals in the intervention group. Escape treatment, in the form of Paracetamol (PCM), was provided if participants complained of pain after exercise. Subjects were advised not to use PCM 24 hours prior to assessment/reading, so that performance of muscle couldn't be affected.¹⁹ Subjects on disease-modifying anti rheumatic-drugs (DMARD's) were continue to take.¹⁷

Before and after intervention assessment was taken using Tinel and Phalen tests, nerve conduction study, functional status scale to check the hand functional ability, symptom severity scale to evaluate symptoms and Jamar hand held dynamometer for assessing the grip strength of hand.

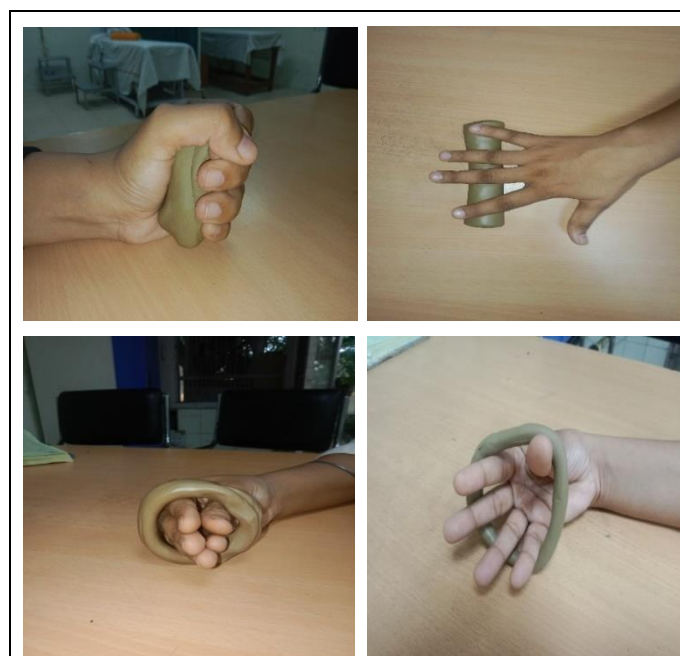


Fig 1. Exercise performed by Subjects

Data Analysis

The data was analysed using SPSS (STATISTICAL PACKAGE OF SOCIAL SCIENCES) statistics version 16.0. Mean $\pm$ SD was calculated for demographic data. For within group analysis the effect of treatment was analysed by repeated measures of ANOVA followed by post-hoc analysis. Pre and post assessment data was analysed using paired t- test. Comparison was done between the groups for all the variables (grip strength, symptom severity, functional status, nerve conduction velocity, pain severity, disease activity) using independent t-test. For all statistical tests, p value < 0.05 was taken to indicate a significant study.

Result

The mean age of participants was 41.6 ± 8.76 years and 44.87 ± 8.94 years in EG and CG respectively. There was no statistically significant difference was found at baseline in between both groups ($p=0.321$). Table 1.1 Shows post hoc pairwise comparison was done by using Bonferroni correlation of NPRS, BCTQ-SSS, BCTQ-FSSS, DAS-28, Grip Strength at the baseline, at 2 weeks and at 6 weeks follow up assessment of all variables in both the groups.

Variable	Experimental group				Control group			
	Mean $\pm$ SD		Mean differences	P value	Mean $\pm$ SD		Mean differences	P value
NPRS	Baseline 6.93 $\pm$ 1.79	2 weeks 4.70 $\pm$ 1.33	2.233	0.000**	Baseline 5.80 $\pm$ 2.40	2 week 5.20 $\pm$ 2.04	0.600	0.100 ^{NS}
	2 weeks 4.70 $\pm$ 1.33	6 weeks 2.43 $\pm$ 1.88	2.267	0.000**	2 week 5.20 $\pm$ 2.04	6 week 4.20 $\pm$ 2.21	1.000	0.008**
	Baseline 6.93 $\pm$ 1.79	6 weeks 2.43 $\pm$ 1.88	4.500	0.000**	Baseline 5.80 $\pm$ 2.40	6 week 4.20 $\pm$ 2.21	1.600	0.010**
BTCQ Symptoms severity	Baseline 35.87 $\pm$ 6.86	2 week 24.20 $\pm$ 6.79	11.667	0.000**	Baseline 32.07 $\pm$ 9.30	2 week 30.40 $\pm$ 5.36	1.667	0.839 ^{NS}
	2 week 24.20 $\pm$ 6.79	6 week 19.60 $\pm$ 6.56	4.600	0.001**	2 week 30.40 $\pm$ 5.36	6 week 27.53 $\pm$ 5.64	2.867	0.019*
	Baseline 35.87 $\pm$ 6.86	6 week 19.60 $\pm$ 6.56	16.267	0.000**	Baseline 32.07 $\pm$ 9.30	6 week 27.53 $\pm$ 5.64	4.533	0.125 ^{NS}
BTCQ- Functional status	Baseline 23.20 $\pm$ 8.25	2 week 16.60 $\pm$ 4.94	6.600	0.001**	Baseline 20.13 $\pm$ 6.03	2 week 18.93 $\pm$ 5.02	1.231	1.000 ^{NS}
	2 week 16.60 $\pm$ 4.94	6 week 13.07 $\pm$ 5.05	3.533	0.000**	2 week 18.93 $\pm$ 5.02	6 week 17.60 $\pm$ 4.81	1.331	0.236 ^{NS}
	Baseline 23.20 $\pm$ 8.25	6 week 13.07 $\pm$ 5.05	10.133	0.000**	Baseline 20.13 $\pm$ 6.03	6 week 17.60 $\pm$ 4.81	2.532	0.452 ^{NS}
Disease Activity	Baseline 4.06 $\pm$ 0.98	2 week 3.40 $\pm$ 0.75	0.657	0.001**	Baseline 3.90 $\pm$ 0.99	2 week 3.60 $\pm$ 0.79	0.351	1.000 ^{NS}

	2 week 3.40 ± 0.75	6 week 2.96 ± 0.62	0.447	0.022*	2 week 3.60 ± 0.79	6 week 3.57 ± 0.69	0.034	0.123 ^{NS}
	Baseline 4.06 ± 0.98	6 week 2.96 ± 0.62	1.104	0.000**	Baseline 3.90 ± 0.99	6 week 3.57 ± 0.69	0.330	1.000 ^{NS}
Grip strength	Baseline 33.50 ± 8.87	2 week 35.42 ± 8.52	1.923	0.021*	Baseline 40.92 ± 12.27	2 week 41.27 ± 12.27	0.351	1.000 ^{NS}
	2 week 35.42 ± 8.52	6 week 37.61 ± 7.99	2.185	0.000**	2 week 41.27 ± 12.27	6 week 42.92 ± 12.63	1.655	0.000**
	Baseline 33.50 ± 8.87	6 week 37.61 ± 7.99	4.109	0.001**	Baseline 40.92 ± 12.27	6 week 42.92 ± 12.63	2.006	0.036*
*The mean difference was significant when value of p was ≤ 0.05. NS- Non Significant (p > 0.05)								

Within group analysis of NPRS, BCTQ-SSS, BCTQ-FSSS, DAS-28, Grip Strength reflected that there was highly statistically significant difference in pain intensity at 2 weeks (p=0.00) and 6 weeks (p=0.00) in the experimental group. However, there was no significant difference at week 2 (p=0.100) for control group although at week 6 there was statistically significant difference (p=0.010) found for pain intensity and grip strength.

Table 1.2. shows analysis of data done by independent paired t-test with repeated measures with a Greenhouse-Geisser correlation as assumption of sphericity violated for nerve conduction study (SCV, MCV and DML) in both the groups.

Variable	Experimental group				Control group			
NCV-SCV	Mean ±SD		t-value	P value	Mean ±SD		t-value	P value
	Baseline 31.57 ± 9.53	2 week 37.67 ± 7.73	-2.782	0.015*	Baseline 30.18 ± 8.75	2 week 30.92 ± 9.96	-0.666	0.516 ^{NS}
NCV-MCV	Baseline 47.52 ± 12.19	2 week 51.41 ± 13.14	-1.460	0.166 ^{NS}	Baseline 47.33 ± 12.67	2 week 51.19 ± 11.37	-2.010	0.064 ^{NS}
NCV-DML	Baseline 4.65 ± 2.02	2 week 4.50 ± 1.25	0.263	0.796 ^{NS}	Baseline 4.21 ± 0.63	2 week 3.92 ± 0.74	1.742	0.103 ^{NS}
*The mean difference was significant when value of p was ≤ 0.05. NS- Non Significant (p > 0.05)								

Within group analysis of NCV-SCV, MCV and DML reflected that there was statistically significant difference in sensory conduction velocity after 6 weeks (p=0.05) in the experimental group while control group showed no significant difference after 6 weeks.

Table 1.3. represents the between group analysis of NPRS, BCTQ-SSS, BCTQ-FSSS, DAS-28, Grip Strength and NCV (SCV, MCV and DML) by using unpaired t-test at baseline, at 2 week and at 6 week in both the groups.

Variable	Week	Group A (Mean±SD)	Group B (Mean±SD)	t-value	p-value
NPRS	Baseline	6.93 ± 1.79	5.80 ± 2.40	1.467	0.154 ^{NS}
	Week 2	4.70 ± 1.33	5.20 ± 2.04	-0.794	0.434 ^{NS}
	Week 6	2.43 ± 1.88	4.20 ± 2.21	-2.358	0.026*
BCTQ-SSS	Baseline	35.87 ± 6.86	32.07 ± 9.30	1.273	0.213 ^{NS}
	Week 2	24.20± 6.79	30.40 ± 5.36	-2.775	0.010*
	Week 6	19.60 ± 6.56	27.53 ± 5.64	-3.552	0.001**
BCTQ-FSS	Baseline	23.20 ± 8.25	20.13 ± 6.03	1.162	0.255 ^{NS}
	Week 2	16.60 ± 4.94	18.93 ± 5.02	-1.283	0.210 ^{NS}
	Week 6	13.07 ± 5.05	17.60 ± 4.81	-2.518	0.018*
DAS28	Baseline	4.06 ± 0.98	3.90 ± 0.98	0.458	0.651 ^{NS}
	Week 2	3.40 ± 0.75	3.60 ± 0.79	-0.686	0.498 ^{NS}
	Week 6	2.96 ± 0.62	3.57 ± 0.69	-2.539	0.017 *
Grip Strength	Baseline	33.50 ± 8.87	40.92 ± 12.27	-1.898	0.068 ^{NS}
	Week 2	35.42 ± 8.52	41.27 ± 12.27	-1.516	0.141 ^{NS}
	Week 6	37.61 ± 7.99	42.92 ± 12.63	-1.378	0.179 ^{NS}
NCV-SCV	Baseline	31.57 ± 9.53	30.18 ± 8.75	0.417	0.680 ^{NS}
	After 6 weeks	37.66 ± 7.73	30.92 ± 9.96	2.071	0.048*
NCV-MCV	Baseline	47.52 ± 12.19	47.33 ± 12.67	0.042	0.967 ^{NS}
	After 6 weeks	51.41 ± 13.14	51.19 ± 11.37	0.049	0.961 ^{NS}
NCV-DML	Baseline	4.65±2.02	4.21±0.63	0.812	0.424 ^{NS}
	After 6 weeks	4.50±1.25	3.92±0.74	1.545	0.134 ^{NS}
*The mean difference was significant when value of p was ≤ 0.05.					
NS- Non Significant (p > 0.05)					

Discussion

Laser therapy along with strengthening exercises shows significant benefits for patients of CTS with RA. Laser therapy, also called as photo biomodulation, can reduce pain, inflammation, swelling and synovitis²³. Photons produced by laser therapy are absorbed in the cells which increased ATP production, induce cellular events such as DNA synthesis and replication, cell proliferation, cell differentiation and protein synthesis²⁴. Therapeutic putty is made up of borosiloxane chain compounds. Its resistance to deformation is directly proportional to the applied force²². This resistance makes it effective as a therapeutic tool. When used in exercises with progressively increasing resistance, it stimulates protein synthesis in muscles, leading to an increase in muscle volume. Strengthening exercises improve dexterity, joint stability and functionality of the hands in rheumatoid arthritis, which helps in reduction of pain, improve hand function and better QOL.

Laser therapy has been shown to improve joint function and reduce swelling, which can contribute to enhanced functional abilities. When combined with strengthening exercises, this multi-modal

treatment likely addresses both the inflammatory and neurological components of CTS, leading to a significant improvement in FSS.²⁵ Strengthening exercises improve muscle strength but may not effectively reduce inflammation or nerve compression, which are primary contributors to functional limitations in CTS patients with RA. This might explain why functional status as measured by the FSS did not improve significantly in the exercise-only group.²⁶ Strengthening exercises are important for improving dexterity and function but work best when combined with pain-reducing modalities like laser therapy.^{22, 27} The significant improvements in DAS28 for both groups can be explained as strengthening exercises alone help reduce joint stiffness and improve muscle strength,²⁸ while laser therapy provides additional anti-inflammatory benefits.²¹ The combination of the two therapies likely enhances this effect by addressing both the inflammatory processes and musculoskeletal dysfunction typical in RA patients with CTS. Laser therapy promotes the regeneration of nerve tissues by stimulating ATP production and enhancing mitochondrial function in nerve cells.²¹ This neuromodulatory effect can help

restore nerve conduction, contributing to a significant improvement in SCV in the laser with exercise group.

Conclusion

This study highlights the significant benefits of combining laser therapy with strengthening exercises in the treatment of Carpal Tunnel Syndrome (CTS) in patients with Rheumatoid Arthritis (RA). The experimental group demonstrated a statistically significant reduction in pain intensity and symptom severity, compared to the control group. The experimental group also exhibited a significant improvement in functional status and disease activity, indicating that the combination therapy not only addresses CTS symptoms but also improves overall disease management. Additionally, sensory nerve conduction velocity improved significantly in the experimental group, while the control group showed minimal changes. Grip strength was improved significantly in both the groups. These findings underscore the efficacy of laser therapy in significantly enhancing pain relief, functional capacity, nerve function, reducing symptoms severity and lowering disease activity in CTS patients with RA, suggesting its potential as a valuable therapeutic intervention.

References

1. Kaya Subaşı, P., Güler, T., Yurdakul, F. G., Ataman, Ş., & Bodur, H. (2021). Carpal tunnel syndrome in patients with rheumatoid arthritis and psoriatic arthritis: an electrophysiological and ultrasonographic study. *Rheumatology international*, 41(2), 361-368.
2. Ibrahim, I., Khan, W. S., Goddard, N., & Smitham, P. (2012). Carpal tunnel syndrome: a review of the recent literature. *The open orthopaedics journal*, 6, 69.
3. Saffan, A. M., Zaky, L. A., Mohammed, M. M., & Eweda, R. S. (2017). Comparison of the effectiveness of low level laser therapy plus exercises and phonophoresis plus exercises in treatment of idiopathic carpal tunnel syndrome. *Journal of Advanced Pharmacy Education & Research* | Oct-Dec, 7(4), 372.
4. Sakthiswary, R., & Singh, R. (2017). Has the median nerve involvement in rheumatoid arthritis been overemphasized?. *Revista brasileira de reumatologia*, 57(2), 122-128.
5. Bîrsanu, L., Vulpoi, G. A., Cuciureanu, D. I., Antal, C. D., Popescu, I. R., & Turliuc, D. M. (2024). Carpal tunnel syndrome related to rheumatic disease. *Experimental and Therapeutic Medicine*, 28(4), 389.
6. Simovic, D., & Weinberg, D. H. (2000). Carpal tunnel syndrome. *Archives of neurology*, 57(5), 754-755.
7. Genova, A., Dix, O., Saefan, A., Thakur, M., Hassan, A., & Arguello, M. T. (2020). Carpal tunnel syndrome: a review of literature. *Cureus*, 12(3).
8. Bîrsanu, L., Vulpoi, G. A., Cuciureanu, D. I., Antal, C. D., Popescu, I. R., & Turliuc, D. M. (2024). Carpal tunnel syndrome related to rheumatic disease. *Experimental and Therapeutic Medicine*, 28(4), 389.
9. Nusrat, A. (2020). Diagnosis of carpal tunnel syndrome in perspective of clinical features, neurophysiological studies and high resolution ultrasound. *World Journal of Advanced Research and Reviews*, 6(3), 086-096.
10. Anwar, I., Ameer, A., Azam, S., Khalid, M., & Asim, H. M. (2019). Hand function among patients with carpal tunnel syndrome. *Open Journal of Therapy and Rehabilitation*, 7(04), 170.
11. Dimple C, Joginder Y, Harpreet S, Savarna, Poonam D. (2022). Relationship of Strength with Pain and Function of Hand in Female Patients with Chronic Rheumatoid Arthritis. *Biosci.Biotech.Res.Comm.* 15(1).
12. Hossein-Khannazer, N., Arki, M. K., Keramatnia, A., & Rezaei-Tavirani, M. (2022). Low-level laser therapy for rheumatoid arthritis: a review of experimental approaches. *Journal of Lasers in Medical Sciences*, 13, e62.
13. Majithia, V., & Geraci, S. A. (2007). Rheumatoid arthritis: diagnosis and management. *The American journal of medicine*, 120(11), 936-939.
14. Abdullah, A. Y., Yousif, R. A., Suliman, A. G., Idris, A. A. I., Hassan, S. A., Ali, S. I., ... & Mohammed, B. (2023). The Impact of Rheumatoid Arthritis (RA) in Median Nerve Area in the Wrist Joint: A Case-Control Study. *Cureus*, 15(5).
15. Feldon, P., & Terrono, A. L. (2006). Carpal tunnel syndrome in rheumatoid arthritis. *Techniques in Orthopaedics*, 21(1), 42-47.
16. Evcik, D., Kavuncu, V., Cakir, T., Subasi, V., & Yaman, M. (2007). Laser therapy in the treatment of carpal tunnel syndrome: a randomized controlled trial. *Photomedicine and laser surgery*, 25(1), 34-39.
17. Ekim, A., & Colak, M. (2007). Effect of low level laser therapy in rheumatoid arthritis patients with carpal tunnel syndrome. *Swiss medical weekly*, 137(2324), 347-352.
18. Stoffer-Marx, M. A., Klinger, M., Luschin, S., Meriaux-Kratochvila, S., Zettel-Tomenendal, M., Nell-Duxneuner, V., ... & Stamm, T. A. (2018). Functional consultation and exercises improve grip strength in osteoarthritis of the hand—a randomised controlled trial. *Arthritis research & therapy*, 20, 1-11.
19. Choudhry D, Yadav J, Singh H, Savarna, Dhankher P. (2021). Effects of Hand Strengthening Exercise on Various Hand Functions in Female Patients of Chronic Rheumatoid Arthritis: A Case-control Study. *J Clin of Diagn Res.* 15(4): YC01-YC04.
20. Chow, R. T., Johnson, M. I., Lopes-Martins, R. A., & Bjordal, J. M. (2009). Efficacy of low-level laser therapy in the management of neck pain: a systematic review and meta-analysis of randomised placebo or active-treatment controlled trials. *The Lancet*, 374(9705), 1897-1908.
21. Naeser, M. A. (2006). Photobiomodulation of pain in carpal tunnel syndrome: review of seven laser therapy studies. *Photomedicine and Laser Therapy*, 24(2), 101-110.
22. Choudhry, D., Singh, H., Yadav, J., Dev, S., & Kalra, S. (2024). Therapeutic Putty-based Hand Strengthening Exercises to Improve Hand Function and Quality of Life in

- Patients with Chronic Rheumatoid Arthritis. *Indian Journal of Physical Therapy and Research*, 6(1), 39-45.
23. Li, Z. J., Wang, Y., Zhang, H. F., Ma, X. L., Tian, P., & Huang, Y. (2016). Effectiveness of low-level laser on carpal tunnel syndrome: A meta-analysis of previously reported randomized trials. *Medicine*, 95(31), e4424.
 24. Unver, S., & Akyolcu, N. (2018). The effect of hand exercise on reducing the symptoms in hemodialysis patients with carpal tunnel syndrome. *Asian journal of neurosurgery*, 13(01), 31-36.
 25. Stergiou, V., & Papadopoulos, P. (2018). Low-Level Laser Therapy for Carpal Tunnel Syndrome in Patients with Rheumatoid Arthritis: A Clinical Trial. *Journal of Clinical Rheumatology*, 24(6), 324-330.
 26. Yeh, J. H., & Lee, T. H. (2022). Effect of Strengthening Exercises on Functional Status in Rheumatoid Arthritis Patients with Carpal Tunnel Syndrome. *Journal of Rehabilitation Research and Development*, 59(8), 1237-1245.
 27. Barbosa, R., Marcolino, A., Souza, V., Bertolino, G., Fonseca, M., & Guirro, R. (2017). Effect of low-level laser therapy and strength training protocol on hand grip by dynamometry. *Journal of lasers in medical sciences*, 8(3), 112.
 28. Szewczyk, D., Sadura-Sieklucka, T., Sokołowska, B., & Książopolska-Orłowska, K. (2021). Improving the quality of life of patients with rheumatoid arthritis after rehabilitation irrespective of the level of disease activity. *Rheumatology International*, 41(4), 781-786.
 29. Retameiro, A. C. B., Neves, M., Tavares, A. L. D. F., Boaro, C. D. T., Rodriguez, D. F. S., Leal, T. S. D. S., ... & Ribeiro, L. D. F. C. (2023). Resistance exercise and low-level laser therapy improves grip strength and morphological aspects in the ankle joint of Wistar rats with experimental arthritis. *The Anatomical Record*, 306(4), 918-932.
 30. Jiménez-del-Barrio, S., Cadellans-Arróniz, A., Ceballos-Laita, L., Estébanez-de-Miguel, E., López-de-Celis, C., Bueno-Gracia, E., & Pérez-Bellmunt, A. (2022). The effectiveness of manual therapy on pain, physical function, and nerve conduction studies in carpal tunnel syndrome patients: a systematic review and meta-analysis. *International Orthopaedics*, 46(2), 301-312.
 31. Hojjati, F., Afjei, M. H., Takamjani, I. E., Rayegani, S. M., Sarrafzadeh, J., Raeissadat, S. A., & Payami, S. (2020). The effect of high-power and low-power lasers on symptoms and the nerve conduction study in patients with carpal tunnel syndrome. A prospective randomized single-blind clinical trial. *Journal of lasers in medical sciences*, 11(Suppl 1), S73.
 32. Rayegani, S. M., Bahrami, M. H., Eliaspour, D., Raeissadat, S. A., Samakoosh, M. S. T., Sedihgipour, L., & Kargozar, E. (2013). The effects of low intensity laser on clinical and electrophysiological parameters of carpal tunnel syndrome. *Journal of lasers in medical sciences*, 4(4), 182.