A MULTIMODAL COMPREHENSIVE PHYSICAL THERAPY APPROACHES IN THE MANAGEMENT OF MILD TO MODERATE CARPAL TUNNEL SYNDROME FOR LONG-TERM IMPROVEMENT

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RESUMEN

El síndrome del túnel del carpo (STC) es el trastorno de atrapamiento de nervios periféricos más prevalente, afectando aproximadamente al 10% de la población. A pesar de su prevalencia, no existe un consenso claro sobre el tratamiento óptimo de terapia física a largo plazo. Este estudio investiga la efectividad de un enfoque multimodal que combina terapia manual, técnicas neurodinámicas y terapia láser de alta intensidad (HILT) para manejar el STC leve a moderado. Los hallazgos sugieren que este enfoque integral puede reducir los síntomas, mejorar la función de la muñeca y prevenir la progresión de la enfermedad durante más de seis meses. Esta estrategia ofrece un tratamiento conservador prometedor que podría evitar la necesidad de intervención quirúrgica en los casos iniciales de STC.

ABSTRACT

Carpal Tunnel Syndrome (CTS) is the most prevalent peripheral nerve entrapment disorder, affecting approximately 10% of the population. Despite its prevalence, there is a lack of consensus on the optimal long-term physical therapy treatment. This study investigates the effectiveness of a multimodal approach that combines manual therapy, neurodynamic techniques, and High-Intensity Laser Therapy (HILT) in managing mild to moderate CTS. The findings suggest that this comprehensive approach can reduce symptoms, improve wrist function, and prevent disease progression over a period longer than six months. This strategy offers a promising conservative treatment that may avoid the need for surgical intervention in early-stage CTS cases.

1. INTRODUCTION

Carpal Tunnel Syndrome (CTS) is the most common nerve entrapment syndrome, with its prevalence increasing over the past decades. It affects approximately 10% of the American population (American Academy of Neurology, 1993)1, and 90% of these cases are diagnosed as peripheral entrapment neuropathies (Burton C.L et al., 2016).2 In Mexico, 61% of patients prefer to avoid surgery (Lores-Peniche J.A et al., 2019).3

CTS typically presents with unilateral or bilateral painful paresthesia in the wrist, particularly in the median nerve distribution. This is caused by nerve compression within the confined osteofibrous canal known as the carpal tunnel (Olney RK, 2001).4 Studies have highlighted biomechanical factors such as wrist posture as possible contributors to increased pressure in the carpal tunnel, leading to the development of CTS (Harris-Adamson C et al., 2015).5

CTS is also recognized as one of the primary causes of neuropathic pain, defined as pain resulting from a lesion or disease affecting the somatosensory system (IASP)6, which can lead to various sensory disturbances in the hand (Zanette G et al., 2006).7 Conservative treatments have shown effectiveness in improving symptoms and wrist function in mild to moderate CTS for up to 3 months (Klokkari D, 2018).8 However, there is limited evidence supporting long-term efficacy, beyond 6 months, without recurrence (Huisstede BM et al., 2018; Karjalanen T et al., 2022).9,10

Given these findings, there is a need for an evidence-based, first-line conservative treatment protocol aimed at controlling the progression of CTS, preventing symptom deterioration, and avoiding surgical intervention in mild to moderate cases. This study explores the impact of physical therapy modalities, such as manual therapy, neurodynamic techniques, and high-intensity laser therapy, to determine their long-term effectiveness in managing CTS.

2. BACKGROUND

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2.1 ANATOMY, BIOMECHANIC PATHOPHYSIOLOGY OF CARPAL TUNNEL SYNDROME

2.1.1 Anatomy: The carpal tunnel is a narrow passage in the wrist formed by the carpal bones on the dorsal side and the transverse carpal ligament on the volar side. Inside the tunnel are nine flexor tendons (four from the flexor digitorum superficialis, four from the flexor digitorum profundus, and one from the flexor pollicis longus) and the median nerve, which is the most superficial structure. This nerve is highly susceptible to compression due to its position between the transverse ligament and cubital bursa. The carpal tunnel also contains the radial and ulnar bursae (Erickson M et al., 2019).11

2.1.2 Biomechanic: Biomechanical studies suggest that extreme wrist extension (>33°) or flexion (>49°) increases the pressure inside the carpal tunnel, elevating the risk of developing CTS (Harris-Adamson C et al., 2015).5

2.1.3 Pathophysiology: CTS occurs due to compression of the median nerve inside the carpal tunnel. Various factors contribute to increased pressure, including tendon inflammation, edema, manual activities, and hormonal changes(Olney RK, 2001).4 Prolonged compression leads to ischemia of the median nerve, reducing blood flow to the nerve layers (epineurium, perineurium, and endoneurium), resulting in neural ischemia and subsequent paresthesia (Skirven TM et al., 2011).12

Prolonged ischemia triggers edema in the nerve trunk due to fluid buildup in the carpal tunnel, exacerbated by the lack of lymphatic drainage. Over time, this causes extraneural and intraneural fibrosis, demyelination, and eventual axon degeneration (Schmid AB, 2020; Dahlin LB et al, 2024).13,14

2.2 CLINICAL MANIFESTATIONS

Carpal Tunnel Syndrome (CTS) presents with a variety of clinical manifestations primarily due to the compression of the median nerve. Common symptoms include paresthesia, sensory disturbances, numbness, and tingling in the fingers, especially the thumb, index, middle, and radial side of the ring finger. Patients may also experience pain, thenar muscle atrophy, weakness, and occasionally swelling on the palmar side of the wrist (Jiménez del Barrio et al., 2022; Yoshii Y et al., 2020).15,16 These symptoms affect both the motor (atrophy, weakness) and sensory (tingling, pain) functions of the median nerve distribution in the hand (Erickson M, 2019).11 CTS is one of the most common peripheral entrapment neuropathies, a group of conditions affecting the peripheral nervous system (Finnerup et al., 2016; Schmid AB et al., 2020).17,13

2.3 2.1 MEDIAN NERVE PATHOLOGY AND DIFFERENTIAL DIAGNOSIS IN CARPAL TUNNEL SYNDROME

Pathology affecting the median nerve can disrupt all downstream nerve functions, sometimes causing pain that extends proximally to the shoulder. This is an important diagnostic consideration to rule out brachial plexus compression, which is not typical of CTS (Erickson M et al., 2019).11

A detailed medical history is crucial for understanding potential injury mechanisms and contributing factors. It also helps to evaluate occupational, psychological, and social influences, aiding in the differential diagnosis (Schmid AB et al., 2020).13

When considering CTS, it's essential to rule out other conditions such as cervical radiculopathy, thoracic outlet syndrome, diabetic neuropathy, and other median nerve pathologies. The anamnesis and history of the patient are key tools in identifying these conditions and establishing risk factors (Erickson M et al., 2019).11 A comprehensive approach, combining clinical examinations and electrodiagnostic tests, further enhances diagnostic accuracy (Keith MW et al., 2009).18

2.3.1 ELECTRODIAGNOSTIC TESTING

Electrodiagnostic studies, such as nerve conduction tests, are often considered the gold standard for diagnosing CTS. These tests assess the velocity of sensory conduction and have a sensitivity ranging from 49% to 84%, with a specificity around 95% (De Jesus Filho AG et al., 2014).19 Despite their value, they can yield false negatives or positives, and some patients may lack access to such tests (Klokkari D, 2018).8 Diagnostic ultrasound serves as an initial screening tool for detecting anatomical variations (Jiménez del Barrio et al., 2022; Yoshii Y et al., 2020).15,16

2.3.2 PROVOCATIVE TESTS

Provocative tests are essential components of physical examination in CTS diagnosis. These tests aim to elicit symptoms during moderate stages of the syndrome (Zhang D, 2020).20

Phalen's Test and Tinel's Test are sensory evoked tests that increase carpal tunnel pressure, inducing paresthesia in the median nerve distribution. Phalen's test has a sensitivity of 42% to 91% and a specificity of 55% to 98%, while Tinel's test shows a sensitivity between 38% and 100% and a specificity of 55% to 80% (Al-Dabbagh KAO et al., 2013).21 The accuracy of these tests can vary based on the examiner's skill. Tinel's Test involves tapping the median nerve at the wrist and assessing for tingling or pain. Phalen's Test requires holding the wrist in full palmar flexion, with symptoms typically appearing within a minute (Ma H et al., 2012).22

Additionally, the Hand Elevation Test, with a specificity of 88.9% and sensitivity of 86.7%, is a simple test that doesn't require advanced expertise. Patients raise both hands above their heads and report any paresthesia or numbness within two minutes (Ma H et al., 2012).22

Finally, the Carpal Compression Test (Durkan's Test), where pressure is applied directly to the carpal area for 30 seconds, has a sensitivity of 71% but a lower specificity of 22% (Zhang D, 2020).20

This organized approach allows for a thorough clinical diagnosis and aids in determining the most appropriate treatment plan for CTS.

2.3 TREATMENT

CTS can be managed with both conservative and surgical treatments, depending on the severity. Conservative treatments are advised for individuals experiencing mild to moderate symptoms who prefer to delay or avoid surgery. (Zarrin M, 2023).23

Studies show that approximately 60-80% of patients with mild to moderate carpal tunnel syndrome respond well to conservative management, which may include splinting, physical therapy, or corticosteroid injections to relieve pain and reduce inflammation. For severe or unresponsive cases, which account for 20-30% of patients, surgical release of the carpal tunnel is often necessary to alleviate pressure on the median nerve and restore function. Research highlights that early intervention with appropriate treatment—whether conservative or surgical—can prevent long-term damage and improve outcomes (Dahlin LB et al., 2024; Jafari M et al., 2023)14,24

2.3.1 MANUAL THERAPY

Manual therapy for CTS focuses on alleviating compression and improving symptoms through soft tissue and joint mobilizations, particularly carpal bone manipulations, to reduce nerve tethering and enhance nerve gliding (Jiménez del Barrio et al., 2022). It has been shown to decrease pain, improve physical function, and enhance nerve conduction through neurophysiological effects in the nervous system (Jiménez del Barrio et al., 2022).15

Active wrist movements restore motor function and alleviate pain by improving nerve excitability and addressing micro-positional faults (Zaralieva A, 2020; Ceylan I et al., 2023).25,26 Combining manual therapy with night splinting, which maintains a neutral wrist position, offers additional benefits like improved circulation and reduced inflammation (Hernández-Secorún M et al., 2021).27

A study integrating cervical manual therapy with conventional physical therapy demonstrated sustained symptom relief and pain reduction for up to six months, highlighting the efficacy of a multifaceted approach (Zarrin M, 2023).23

SUGGESTED PROTOCOL AND CONSIDERATIONS

- **Direct myofascial release therapy** applied to the descending region of the trapezius which breaks the tissue adhesions or restrictions inside or around the tendons (Shem K et al., 2020).28
- **A direct myofascial stretch** of the carpal ligament performed by wrist extension against a wall with gentle retraction of the thenar eminence for 30 seconds. This technique increases the carpal tunnel's cross-sectional area, reducing numbness, tingling, and enhancing strength (Shem K et al., 2020).28
- **Active Wrist Mobilization with Movement:** Involves controlled wrist flexion and extension (10 repetitions, 3 sets) with sustained manual carpal bone glides to improve range of motion and pain. Glides are selected based on their effectiveness in reducing pain during active wrist motion, followed by passive overpressure (Ceylan I et al., 2023).26

2.3.1 NEURODYNAMIC TECHNIQUES

Neurodynamic techniques are neural mobilization exercises that have been suggested to enhance the neurophysiological functions such as nerve conduction of the median nerve to reduce the symptoms and restoring its normal movement (Jiménez del Barrio et al., 2022).15

When treating CTS, these techniques are combined controlled arm and neck movements which facilitates longitudinal movement of the median nerve along its entire course promoting effects on the nervous system without causing nerve irritation (Coppieters et al., 2009).29

Sliding nerve gliding exercises improve nerve movement, reduce tension, and alleviate edema and inflammation. They restore hand function (e.g., grip strength) by decreasing adhesions in the carpal tunnel and reducing symptom recurrence (Ballestero-Pérez R et al., 2017).30 Additionally, a study has suggested that neurodynamics of the brachial plexus and proximal segments of the median nerve can elongate the nerve bed, thereby promoting facilitation of nerve gliding which contributes to improve symptoms associated with CTS (Coppieters et al., 2009).29

A study showed that patients incorporating neurodynamic exercises showed reduced need for surgery (43%) compared to those without these exercises (71.2%) (Horng YS et al., 2011).31

SUGGESTED PROTOCOL AND CONSIDERATIONS

Perform two simultaneously active movements (3 sets of 10 repetitions during 7 seconds): affected arm in 90 degrees of abduction and external rotation, elbow extension, supinated forearm, wrist in neutral position, fingers in extension and cervical ipsilateral lateral flexion. While flexing the elbow, simultaneously do a cervical ipsilateral flexion to the other side, then while extending the elbow, do a cervical ipsilateral flexion

following the movement (Figure 1) (Coppieters et al., 2009).29

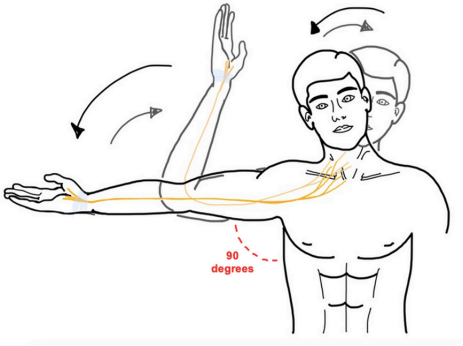

Figure 1: Sliding nerve gliding exercises. Combined controlled arm and neck movements which facilitates longitudinal movement of the median nerve.

2.3.1 HIGH INTENSITY LASER THERAPY

"Laser," which stands for Light Amplification by Stimulated Emission of Radiation, is a device that emits a single wavelength characterized by coherent and constant phases, propagating in one direction (Kumnoonsup, 2023).32 It is a non-invasive and painless treatment method that uses light to promote cellular activity and tissue regeneration. By stimulating mitochondria in nerve cells, HILT increases ATP production to aid in nerve tissue repair (Choi H, 2017). 33

Human body absorbs light energy differently based on the wavelength of light, known as chromophores. Class IV lasers, which exceed 500 mW, penetrate tissues deeply, enhancing blood circulation which decreases fluid accumulation in the carpal tunnel, reducing pain and inflammation (Kumnoonsup, 2023).32

High-Intensity Laser Therapy (HILT) improves metabolism, enhances blood circulation, and reduces ischemia and edema in the carpal tunnel, accelerating tissue regeneration and alleviating pain and inflammation. This leads to improved wrist function and mobility (Choi H, 2017).33 HILT, with a power of 500 mW, penetrates deeper tissues, helping in the healing of various injuries, including axonal sprouting in severe cases like neurotmesis (Ashour AA, 2022; Tabatabai, 2016). 34,35 Studies show positive outcomes for Carpal Tunnel Syndrome (CTS) treatment with no adverse effects, though HILT works best alongside other physical therapy methods (Kumnoonsup, 2023).32

SUGGESTED PROTOCOL AND CONSIDERATIONS (KUMNOONSUP, 2023).32

- The study presents a HILT protocol which used the Mectronic healthcare iLux Triax.
- The device operated at a power of 15 watts, emitting three wavelengths simultaneously: 810 nm, 980 nm, and 1,064 nm, with an equal distribution of power among the three wavelengths, resulting in 5 watts for each wavelength.
- The intensity dosage was set at 20 J/cm2.
- The HILT was applied approximately 10 cm proximal to the wrist crease, extending to the palmar crease, covering the specific areas of the fingers where the patient reported numbness or pain (Figure 2).
- The intensity dosage was distributed throughout all areas by placing the probe no more than 1 centimeter away from the skin and moving it at a speed of approximately 30-40 cm/sec.

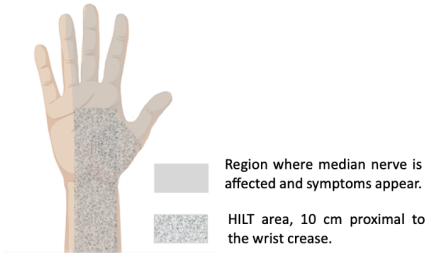

Figure 2: Area where HILT will be applied. (Modified from Biorender with Word Microsoft 365).

RESULTS

According to the multimodal approach of combining manual therapy, neurodynamic techniques, and High-Intensity Laser Therapy (HILT) mentioned in this research, it would be expected that these treatments, when applied together, would lead to a reduction in symptoms and an improvement in the quality of life for patients in managing mild to moderate Carpal Tunnel Syndrome (CTS) (Table 1). Patients reported a marked reduction in pain, improved wrist function, and enhanced nerve conduction. In particular:

- Manual therapy reduced epineural tethering and improved median nerve gliding, alleviating compression within the carpal tunnel (Jiménez del Barrio et al., 2022).15
- Neurodynamic techniques restored median nerve mobility, decreased edema, and improved grip strength (Ballestero-Pérez R et al., 2017).30
- HILT significantly reduced inflammation and promoted tissue regeneration, with no adverse effects reported (Kumnoonsup, 2023).32

These therapies combined may provide long-term symptom relief, extending beyond the typical 3-month period observed in previous studies (Klokkari D, 2018).8 This effect could be sustained for up to 6 months, with many patients avoiding the need for surgical intervention (Horng Y S et al., 2011).31

	Manual Therapy	Neurodynamics	High Laser Intensity Therapy
Reduce pain intensity	15,25	29	32
Antiinflamatory effects	26	29	32
Improves nerve conduction	15	15,28	32
Restores wrist movement and function	15,24	29	32
Promotes blood flow	26		32
Improvements for more than 3 months	23	30	31

Table 1: Comparison between Physical therapy treatments and their effects.

DISCUSSION AND CONCLUSION

The findings suggest that a multimodal physical therapy approach may be the most effective first-line conservative treatment for Carpal Tunnel Syndrome (CTS), particularly for patients who prefer to avoid or delay surgery. This approach, combining manual therapy, neurodynamic exercises, and High-Intensity Laser Therapy (HILT), has shown promising results in improving nerve gliding and pain relief. These outcomes are consistent with previous research, which highlights the significant role physical therapy plays in enhancing nerve function and reducing the symptoms of CTS (Jiménez del Barrio et al., 2022).15

However, it's important to reflect on the limitations of single therapies. While manual therapy can provide short-term relief, it may not be sufficient for long-term benefits unless complemented by other interventions, such as HILT and neurodynamic exercises. Studies have shown that combining these methods leads to superior outcomes compared to using manual therapy alone (Wolny T et al., 2017).35 The positive effects of HILT, particularly with no reported adverse effects, suggest that it could be a valuable adjunct in treating CTS, further enhancing the efficacy of the multimodal approach (Yiğit F et al., 2023).37

Despite these encouraging results, the need for long-term studies remains critical. Further research is required to determine the sustainability of symptom relief provided by this multimodal approach over extended periods, especially considering the chronic nature of CTS. These insights could guide more personalized, effective treatment plans for patients in the future.

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