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EXPLORING THE POSSIBILITIES OF SOME CONTEMPORARY PHYSICAL THERAPY METHODS FOR THE CONSERVATIVE TREATMENT OF CARPAL TUNNEL SYNDROME

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ABSTRACT

Carpal tunnel syndrome (CTS) is the most common compression neuropathy, affecting nearly 5% of the general population. The modern approach to its treatment is complex and includes early diagnosis, prevention and treatment of all conditions and diseases leading to its manifestation.

Many authors have worked on the problems related to the possibilities of physical therapy in treating CTS, but the question of optimal treatment and rehabilitation remains relevant to this day. In practice, various rehabilitation programs are constantly being implemented and developed. Many have demonstrated positive outcomes, but work in this area persists. Every novel approach or integration of established physiotherapeutic and rehabilitation techniques enhances the current methods and expands the potential for more comprehensive functional recovery of the impaired limb, as well as the patient's restoration to their previous lifestyle.

Physical therapy has advanced significantly in recent decades due to the introduction of numerous new techniques and technologies. The article offers a brief literature overview of several contemporary physical medicine approaches that can be applied in the conservative treatment of carpal tunnel syndrome based on their physiological and therapeutic effects. Modern physical therapy approaches can be a viable alternative to established physical therapy methods like ultrasound, low-level laser, iontophoresis, magnetotherapy, TENS, and others. It is crucial to conduct additional qualitative and comprehensive investigations to verify the effectiveness of physical therapy in treating CTS, identify the most efficient ways, and create improved protocols for its conservative treatment.

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Introduction.

First described by Paget in 1854, carpal tunnel syndrome (CTS) is the most common compression neuropathy with an incidence of between 125–515/100,000. CTS occurs due to the compression of the median nerve by the transverse ligament of the wrist. (Conway, 1994) (Corvin, 2006). It occurs in 2 to 5% of the overall population. In the Netherlands, a general population study revealed an incidence of 1% for men and 7% for women. The population prevalence of carpal tunnel syndrome (CTS) in southern Sweden was 3%, with a 95% confidence interval ranging from 2% to 3%.

Typically, the prevalence is higher in women than in males, with a male-to-female ratio of 1.0:1.4. (Ashworth, 2016). Any factors causing a reduction in the width of the carpal tunnel or an enlargement of its components result in nerve compression and related complications. CTS develops because of the compression of the median nerve in the carpal tunnel caused by increased pressure.

The classic carpal tunnel syndrome manifests with sensory and motor impairments in the area of the median nerve, often accompanied by pain. Symptoms worsen with physical exertion on the affected limb. During the initial stages of CTS, the clinical presentation is primarily associated with the involvement of sensory fibres. It is characterised by dull and burning pain in the area of the wrist, extending from the palm to the elbow. The pain typically intensifies at night and is often associated with paresthesia in the second and third fingers of the hand upon awakening. Relief is felt when shaking the hand and letting it hang outside the bed. (Vladeva E, 2014).

The modern approach to managing carpal tunnel syndrome is comprehensive and includes prompt identification, prevention, and treatment of all underlying disorders and diseases contributing to its development. Physical therapy techniques are an effective alternative for the conservative management of this medical condition.

The role of physical therapy in the treatment of carpal tunnel syndrome.

Many authors have worked on the problems related to the possibilities of physical therapy in the treatment of CTS. However, the question of optimal treatment and rehabilitation remains relevant today. In practice, various rehabilitation programs are constantly being implemented and developed. Many have demonstrated positive outcomes, but work in this area persists. Every novel approach or integration of established physiotherapeutic and rehabilitation techniques enhances the current methods and expands the potential for more comprehensive functional recovery of the impaired limb, as well as the patient's restoration to their previous lifestyle (Vladeva E, 2014).

Regardless of the choice of physical treatment modalities for CTS, the physiotherapist is faced with the following tasks:

1. Treatment of pain and other subjective symptoms experienced by the patient (such as reduced sensitivity, abnormal sensations, and trouble gripping objects).
2. Treating oedema and enhancing blood circulation in the affected hand.
3. Enhancing nerve conductivity and promoting regenerative processes.
4. Improving sensory perception, increasing muscle strength, and restoring compromised functions of the affected limb.
5. Preventing fibrotic processes and other potential problems.
6. Treatment targeting the causes and mechanisms of the disease.

The physiotherapist must choose and customise tools and methods based on a functional assessment, neurological and functional status data, results from tests like ENG, ultrasound diagnostics, CT, or MRI, and the patient's psychosomatic condition for best outcomes.

The neurorehabilitation course is tailored to address the patient's motor and sensory problems to resolve their current functional issues.

The neurorehabilitation program should be customised to the specific clinical form and stage of the disease, considering any accompanying conditions that may be part of the cause. It should be personalised, with minimal societal investment to maximise results for the patient's quality of life, regardless of the funding source.(Колева, 2009).

Physical therapy for carpal tunnel syndrome.

Ultrasound therapy is a frequently utilised approach. Some authors suggest that the impact of phonophoresis with corticosteroids is similar to that of corticosteroid injections, making phonophoresis a non-invasive approach that preserves the skin's integrity (Bilgici, 2010) (Rükşen, 2011). Sonicating for a brief period (4–5 min) can enhance the impact of the following electrophoresis using known skin-absorbing capabilities improved by ultrasound's heat and mechanical impacts (Vladeva E, 2014).

Physiotherapy treatment may include ***low-level laser therapy, acupuncture, magnetic therapy, ultra-high frequency currents, interference currents and TENS*** (Karjalanen T, 2022). These physical factors do not address the aetiology and etiopathogenesis of CTS. They are used as a symptomatic treatment, mainly targeting pain and paresthesias.

Physical therapy has advanced significantly in recent decades due to the development of numerous new treatments and technologies.

MLS (Multiwave Locked System) high-energy laser therapy is a precise and safe treatment that is highly effective in alleviating pain, with noticeable results from the initial session. This technology offers quick treatments combining constant and pulse modes to accomplish a triple effect: simultaneously reducing swelling, inflammation, and pain. The device allows for working on a greater region using scanning mode or focusing on trigger points, acupuncture, or painful points. The techniques are appropriate for treating pain from different sources, post-traumatic problems, swelling, joint diseases, spinal issues, nerve disorders, skin conditions, and post-surgery rehabilitation.

Improving blood circulation in the outer layer of the skin is thought to affect the level of blood circulation within the inner layer of nerves. Blood vessels and nerves exhibit similar principles and signals for differentiation and growth, resulting in a coordinated reaction to shared stimuli, including laser treatment. The laser improves peripheral nerve function by boosting blood circulation to the nerves. (Yosifova L, 2023).

Ezzati et al. conducted a double-blind, randomised, controlled research with 98 patients aged 20 to 60. They demonstrated the advantages of high-energy laser radiation at 1.6 W and low fluence of 8 J/cm2 over low-intensity laser therapy (Ezzati, 2020).

Yiğit, et al.'s study, evaluates the impact of high-intensity laser therapy (HILT) on pain, functional status, grip strength, and median nerve cross-sectional area (evaluated using ultrasonography) in individuals with carpal tunnel syndrome. The study included sixty patients diagnosed with carpal tunnel syndrome. Participants in the trial were randomly allocated into two groups, each consisting of 30 patients. The first group received exercises, splinting, and HILT treatment for 10 sessions over two weeks, with specific parameters for the HILT treatment. The second group received splinting, exercises, and sham laser treatment for the same period. The study's findings support the conclusion that hand grip strength rises and the cross-sectional area of the median nerve decreases when a high-intensity laser is applied. The effect has only been shown in the short term, with no evidence of its long-term retention. (Yiğit, 2023).

Extracorporeal shockwave therapy (ESWT) is recognised as a non-invasive and evidence-based physical therapy method for treating CTS. The device utilises pneumatically produced shock waves operating at a low frequency of 5-20 Hz and a pressure ranging from 1 to 5 bar. Extracorporeal shock wave therapy (ESWT) addresses injuries by enhancing local metabolic activity, promoting the reabsorption of tendon calcifications, and triggering natural healing mechanisms in tissues. Stimulating the healing process involves releasing growth factors in tendons and bones, which results in the development of new blood vessels. Enhancing microcirculation through the formation of new blood vessels leads to the encouragement of tissue regeneration and repair. The shock wave therapy process can be described as the body's reaction to acute trauma, triggering inflammation, new tissue development, and regeneration. The wide range of indications of shock wave therapy is determined by its mode of action. The application for carpal tunnel syndrome is focused locally in the area of the transverse carpal ligament. The treatment regimen includes 4-6 sessions, with one or two sessions per week. Therapy is more beneficial during the early phase of the disease and in younger individuals whose carpal tunnel syndrome is linked to excessive work demands. (Soyuer, 2021) (Zaralieva, 2020).

Yujie Xie and colleagues systematically reviewed ten studies involving 433 patients (501 hands). They concluded that shock wave therapy effectively alleviates symptoms and enhances hand function in individuals with carpal tunnel syndrome. They also found that radial shock wave therapy is more effective than focused shock wave therapy in terms of symptom relief and functional recovery. (Yujie Xie, 2022).

A double-blind clinical trial conducted by Vahdatpour et al. involved 60 patients with moderate CTS divided into two groups. Both groups received conservative treatment, which included wrist immobilisation at night for three months, nonsteroidal anti-inflammatory drugs for two weeks, and oral intake of vitamin B1 for one month. The initial group received Extracorporeal Shock Wave Therapy (ESWT) once a week for four weeks. The authors recommend applying ESWT as a conservative treatment for patients with CTS due to its positive impact on reversing clinical symptoms, Energy-dispersiveX-ra y spectroscopy results (EDX), and its lack of adverse effects (Vahdatpour, 2016).

Tecar therapy, also known as ***targeted radiofrequency therapy*** or ***TECAR***, is an electrotherapeutic non-invasive treatment that utilises high-frequency currents. The current creates heat inside the tissues by penetrating them via electromagnetic energy. This effect leads to a slow and regulated rise in internal temperature within the tissues. (Kumaran B, 2019). This action results in cellular activation and dilatation of blood vessels, initiating a natural regeneration process. This mechanism stimulates the release of natural painkillers, compounds that promote biological stimulation and regeneration (primarily cortisol and endorphins), elimination of cellular waste products, reduction of outflow, and inflammatory processes. Endogenous heat produced has a strong anti-inflammatory effect and speeds up tissue repair. The devices combine two modes of operation: capacitive and resistive (Zaralieva, 2020). Various tissues possess unique structures, resulting in distinct tissue resistance. This suggests utilising a different approach to produce heat in each of them selectively. Targeted radiofrequency therapy offers accurate and effective treatment by combining two modes of operation to heat certain tissues at varying depths. Athermic efficiency is achieved by using low-intensity radio frequency to heat the surface tissue layers more efficiently and enhance the function of the lymphatic system. This leads to decreased acute or chronic swelling, enhancement of anti-inflammatory mechanisms, and notable enhancement of cellular and interstitial metabolism. (Binoy Kumaran, 2017).

According to a study by Vahdatpour et al. TECAR can be considered an effective non-invasive treatment for patients, reducing clinical symptoms and enhancing daily activities in patients with mild to moderate carpal tunnel syndrome (Vahdatpour B, 2023). Future research with a bigger sample size and longer follow-up are required to validate these results, providing more significant insights into nerve conduction changes and enhancing the understanding of the clinical effectiveness of TECAR CTS therapy.

Deep oscillations are a modern physical therapy modality with anti-edematous, fibrinolytic, analgesic, and anti-inflammatory properties. While still being validated for treating CTS, it could be considered for conservative treatment of the syndrome. The deep oscillation (DO) approach relies on the Johnson-Rahbek effect, which occurs when an electric potential is supplied at the junction of a metal surface and a semiconductor material surface. Under these conditions, electrostatic attraction and friction forces occur in biological tissues, causing the generation of an oscillation that penetrates deeply up to 8 cm, affecting all tissue components in the applied area (skin, connective tissue, muscles, blood, and lymphatic vessels). The intermittent electrostatic field generated has low intensity (I = 150 A), ranging from 100 to 400 V, and low frequency (f = 5-250 Hz) (Locheva, 2019). Deep oscillations have been clinically proven to provide substantial pain relief and anti-inflammatory effects in both acute and chronic pain conditions. They can also help prevent and reduce lymphedema, aid in fibrous remodelling, reduce fibrosis, promote muscle relaxation, mobilise fascia, and improve range of motion. Hernandes S. et al. proved the fibrinolytic and tissue tension-reducing action of DO in an experimental prospective case-control research. Deep oscillations have been found to induce tissue relaxation, exhibit mild vasoconstrictor action, promote local lymphatic resorption, and decrease fibrosis. (Hernández Tápanes S., 2018). The over twenty-year history of therapeutic use of DO demonstrates their pain-relieving effectiveness in chronic pain associated with certain musculoskeletal and neurological system disorders. As confirmed by objective measurements, the significant enhancement in lymphatic circulation and decreased lymphedema are undeniable. The impact of enhanced tissue nourishment has been demonstrated. Studies have confirmed the anti-inflammatory impact of deep oscillations. (Locheva, 2019). Deep oscillations have demonstrated physiological and therapeutic benefits that suggest they could positively impact the reversal of carpal tunnel syndrome symptoms. Although deep oscillation devices have established programs for treating CTS, additional studies are needed to prove their beneficial effect in patients with this disease.

Biofield therapy is used to manage pain for patients with cancer and chronic pain. Research regarding the impact of biofield treatment on particular somatic illnesses needs to be more comprehensive. Mohammad Reza Nourbakhsh studied the impact of ***oscillating biofield therapy*** (OBFT) on carpal tunnel syndrome symptoms. (Mohammad Reza Nourbakhsh, 2016). Participants were randomly assigned to either the active or placebo treatment groups. The active treatment group underwent six sessions of OBFT within a 2-week timeframe. Patients in the placebo group had an equivalent number of sessions. A significant drop in the number of patients testing positive in the Phalen test (87%; $p = 0.000$), the Tinel test (73%; $p = 0.000$), and experiencing hand paresthesia (80%;

p = 0.000) was observed in patients receiving active treatment. After six months, 86% of patients in the therapy group were still free of pain and had no functional limitations. The authors determined that OBFT could be a beneficial therapy for enhancing the symptoms and limitations of function linked to chronic carpal tunnel syndrome.

Physiotherapy utilising ***high-intensity electromagnetic fields through Super Inductive System (SIS)*** therapy has demonstrated effects on pain reduction, muscle relaxation, muscle activation, and joint mobilisation. SIS focuses on neuromuscular tissue, where the electromagnetic field interacts with the muscles to produce controlled and repetitive contractions. This process helps remove joint obstructions, improve circulation and tissue metabolism, and enhance muscle tone.

Many specialised studies have been developed in recent decades analysing different conservative techniques (https://files.btlnet.com/cor/documents/af40969e-4070-4864-bf4e-b84545dfed99/BTL-6000_SIS_CAT_ELITE_EN103_preview_1473426747_original.pdf). Joint mobilisation is accomplished by repeatedly contracting the muscles that surround the joint capsule. This repeated contraction replaces manual joint mobilisation, resulting in the restoration of joint play. When the electromagnetic field interacts with neuromuscular tissue, it causes neuron depolarisation and muscle contractions. Muscle facilitation or strengthening can be obtained depending on the chosen stimulation frequency. An observational prospective study by Diana Jimbu et al. conducted in 2021-2022 followed 56 patients receiving three SIS therapy sessions per week with the BTL-6000 equipment and daily physical therapies. The study showed that the high-intensity electromagnetic field produced by SIS therapy is effective and safe for treating patients with CTS. It offers substantial advantages by reducing pain and paraesthesia and improving patients' quality of life. (Jimbu D., 2023).

Light therapy has been used since the late 1960s for treating various conditions such as neonatal jaundice, joint discomfort, psoriasis, and vitiligo. The most common forms of phototherapies are low-level laser therapy (LLLT) and ultraviolet (UV) radiation, which differ based on the physical characteristics of the light used.

Recently, it has been proposed that polarisation and a broad light spectrum are crucial components of light therapy. Light waves are filtered to oscillate uniformly, producing polarised light (PL). ***Polarised Light Therapy (PLT)*** uses polarised light to penetrate deeper into tissues and stimulate various biological processes**.** Photobiomodulation (PL) differs from other forms of light therapy by utilising a broader range of wavelengths compared to Low-Level Laser Therapy (LLLT) or Ultraviolet (UV) light (M. Allam N, 2022). The light produced by the Bioptron light therapy system is polarised, low-energy, polychromatic (with wavelengths ranging from 480 to 3400 nm), and incoherent (not in phase unlike laser light) (Raeissadat SA, 2014). Bioptron works by activating cellular processes, improving blood flow, reducing pro-inflammatory cytokines, and increasing plasma levels of anti-inflammatory and fibroblast growth factors. (Zhevago, 2004) (O'Connor, 2003). However, there is limited research assessing the impact of bioptron therapy on symptom alleviation in CTS.

A randomised clinical trial with forty-four patients with mild to moderate carpal tunnel syndrome evaluated the impact of Bioptron on pain symptoms and electroneurographic parameters with splinting for eight weeks. The scientists determined that the therapeutic benefits achieved by using the Bioptron are comparable to those achieved by using a splint (Raeissadat SA, 2014).

An uncontrolled experimental study by Stasinopoulos et al. found that nocturnal pain and paresthesias associated with mild to moderate idiopathic carpal tunnel syndrome were relieved during treatment with polarised polychromatic incoherent light (Bioptron light), and the results were sustained up to six months. Bioptron, polarised polychromatic noncoherent light, was applied perpendicularly to the carpal tunnel area. Each session lasted 6 minutes and took place at a distance of 5-10 cm from the carpal tunnel area. This was done three times a week for four weeks (D. Stasinopoulos, 2005). The authors believe the Bioptron Light is a dependable, secure, and efficient treatment for patients with CTS. However, using alternative therapeutic protocols and light characteristics than those in this study could lead to varying outcomes favouring Bioptron therapy. Controlled clinical trials are necessary to determine this treatment's definitive and comparative efficacy.

GUNA injectable collagen stimulates collagen production by targeting specific anatomical areas using 13 different vials. ***Gunaphoresis*** using collagen ampoules enhances the perineural collagen structure and alleviates localised neural pain. This novel physical therapy strategy is currently being verified for its efficacy in treating CTS and can be regarded as part of its conservative treatment. Tropocollagen, supplied by Guna Collagen Medical Devices, undergoes a process of assembly at the

extracellular matrix (ECM) level via the enzyme lysine hydroxylase into collagen; thus, it functions as a bioscaffold (Milani, 2010). The application of MDs results in the deposition of neosynthesised collagen fibres in the damaged region. This process substantially enhances the mechanical properties of the injured tissue, specifically by restoring its anisotropic characteristics. Proper mechanical support is achieved for optimal operation due to the alignment of collagen fibres in a single direction (Milani, 2019).

This approach offers deep penetration, a high product absorption rate, and no heat effects, making it safe for use on nerve tissues without overheating. All of this occurs without causing any adverse effects and with remarkable tolerability (Brunato, 2021). No research in the scientific literature has conclusively demonstrated the efficacy of this therapy. Considering the established physiological impacts of gunaphoresis, it is essential to recognise its possible beneficial effects in managing clinical symptoms of CTS.

High-tone external muscle stimulation (HTEMS) or high-tone therapy is a novel form of electrotherapy. HTEMS differs from traditional electrotherapy by modulating frequency and amplitude simultaneously, resulting in more significant energy delivery to the tissues. High-tone therapy has gained significant focus for treating many diseases. Its primary effects include energising the body to stimulate cell activity, causing cells and tissues to vibrate and boost metabolism, and releasing pain and inflammation mediators to alleviate pain. High tone power therapy reduces pain and improves function in CTS patients, outperforming physical therapy alone (Abou Shady N, 2019). Despite a number of studies reporting that high-tone therapy significantly alleviated symptoms and signs, the insufficient number and substandard methodological quality of the included studies prevent definitive conclusions regarding the efficacy of HTEMS. This may be an important motivation for future research (Namvar H, 2022).

Kinesio taping involves applying elastic tape to generate small folds in the skin, lift skin tissue, enhance blood circulation, alleviate discomfort, and decrease compression. Application direction, duration, frequency, and tension level are crucial in kinesio taping. Kinesio taping technique has been shown to reduce pain and symptom severity and improve daily activities in patients with carpal tunnel syndrome. (Soyuer, 2021). Kinesio tape application on CTS relieves nerve pressure by elongating the transverse carpal ligament. It decreases muscle spasms, aids in the movement of tendons and fascia, and alleviates pain by suppressing neurological activity. Kinesio taping is suitable for mild to severe carpal tunnel syndrome as it does not disrupt daily activities like an immobilisation splint and has no adverse effects. (Soyuer, 2021).

Virtual rehabilitation for carpal tunnel syndrome Force Feedback utilises haptic devices to deliver effective and engaging feedback during physical treatment. (Tamayo, 2018). Patients interact with virtual apps and do activities within a 3D graphical environment. This can enhance the therapeutic process by increasing engagement and motivation and enabling more authentic and regulated motions. The exercises replicate typical daily activities, aiding patients in restoring the functional skills necessary for daily living. The system is created with the Unity3D game engine, providing a versatile and easy-to-use platform. The advantages of this rehabilitation approach lie in the following aspects:

1. Integrating tactile feedback and virtual environments and simulating daily tasks can enhance therapy by making it more interactive and entertaining for patients. This may result in improved adherence to the rehabilitation program.
2. The system can offer targeted exercises that address the root causes of CTS, perhaps resulting in quicker and more effective rehabilitation.
3. The system emphasises developing a collaborative relationship between the patient and technology, which may result in improved outcomes.

According to research along these lines, Force Feedback haptic devices may be an effective aid in treating carpal tunnel syndrome. Nevertheless, additional investigation is required to validate the long-term efficacy and applicability of this approach. (Tamayo, 2018) (De Paolis, 2018).

Conclusion.

Contemporary approaches of physical therapy such as targeted radiofrequency therapy (TECAR), high-energy laser therapy, extracorporeal shock wave therapy (ESWT), deep oscillation, polarised light therapy (PLT), collagen ampoule gunaforesis, high-tone therapy, virtual rehabilitation

system utilisation, and haptic devices can serve as a viable alternative to established methods of physical therapy like ultrasound therapy, low-level laser therapy, iontophoresis, magnetotherapy, TENS, and others. Although current scientific evidence supports the efficacy of contemporary physical therapy methods in treating carpal tunnel syndrome (CTS), further comprehensive comparative studies with larger patient groups are required to assess the long-term effectiveness of this treatment approach. It is crucial to conduct additional qualitative and comprehensive investigations to verify the effectiveness of physical therapy in CTS, identify the most efficient approaches, and create improved protocols for its conservative treatment. This will enhance awareness among patients and healthcare professionals regarding the advantages of physical therapy in managing the syndrome. Further research investment in this field could enhance the quality of life for many people suffering from carpal tunnel syndrome.

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