

## SHORT- WAVE DIATHERMY - POSSIBLE THERAPEUTIC BENEFITS OF HIGH-FREQUENCY ELECTROMAGNETIC FIELD THERAPY IN PHYSICAL PRACTICE

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**Abstract:** High-frequency electromagnetic fields are a physical modality that is used for treatment and rehabilitation of a range of diseases. The electromagnetic energy generated by high-frequency devices has effects on biological tissues. The effectiveness of shortwave diathermy is related to increase of deep tissue heat and also to electromagnetic energy's non-thermal effect. The physiological action mechanism includes formation of deep tissue endogenous heat, increase in blood flow velocity and vasodilation, and improvement in local blood flow. The therapeutic effects are related to improving the elasticity of soft tissues, reducing muscle spasm and or spasticity, reducing pain in degenerative and traumatic processes, reducing edema, accelerating regeneration, and improving the trophic of peripheral nerves, influencing the inflammatory process. The physiological and therapeutic effects of SWD, suggest the application of this type of therapy in diseases of different nature, and in the recent years literature a number of studies have been reported on the effect of therapy in patients who has suffered COVID-19 and post - COVID-19 syndrome. The aim of this review is to provide an overview of the described therapeutic effects of the practical application of shortwave and ultrashortwave diathermy, including their potential applying in patients with COVID-19 or patients with symptoms of post-COVID-19 syndrome. Materials and methods: For the purposes of this review, a search of currently published literature sources was conducted, which included: reports on the therapeutic application of high-frequency electromagnetic fields, overview articles, systematic reviews, and narrative synthesis regarding the application of short-wave and ultrashort-wave diathermy treatment. The study of scientific articles was carried out in the available databases Pub Med, Google Scholar, Elsevier. The search was conducted for the following keywords: physical therapy modalities, electrotherapy, electromagnetic therapy, diathermy (short-wave therapy), ultrashort-wave diathermy, radiofrequency therapy, deep heat, endogenous heat, inflammation, COVID-19, post-COVID-19 syndrome, reparation. Results: The review of the published scientific information on the therapeutic effects of high-frequency electromagnetic fields found evidence of anti-inflammatory, pain-reducing, trophic-enhancing and tissue regeneration effects of diathermy in various diseases, including lung diseases and including patients with COVID-19, post-COVID-19 syndrome. However, other authors think that there is currently insufficient information on the efficiency, methods of administration, dosage and safety of high-frequency electromagnetic fields, and more studies are necessary regarding their use in patients with COVID-19. Conclusion: The use of short-wave and ultrashort-wave diathermy is associated with potential therapeutic benefits. Anti-inflammatory, pain-reducing effects, improving regeneration, trophicity and tissue elasticity capabilities of this therapy have been described, including in COVID-19 survivors. On the other hand, due to the possibility of tissue injury from high-frequency electromagnetic fields, it is necessary to rigorously refine the need for their administration.

**Keywords:** Physical therapy modalities, Short Wave Diathermy, Ultra-Short Wave Diathermy, deep heat, inflammation, COVID-19, post-COVID-19 syndrom.

### 1. INTRODUCTION

High-frequency electromagnetic fields (HFEMFs) are a physical modality that is used for treatment and rehabilitation of a range of diseases. The electromagnetic energy generated by high-frequency devices has effects on biological tissues (Almaly et al. (2023)). The effectiveness of SWD is related to increase of deep tissue heat and also to electromagnetic energy's non-thermal effect. The physiological action mechanism includes: formation of deep tissue endogenous heat, increase in blood flow velocity and vasodilation, and improvement in local blood flow. The study of the mechanisms of action of EMFs has been carried out for a long period of time. Experimental and clinical results have been reported in a number of scientific publications. Their effects on human tissues, which can have a thermal and non-thermal character, have been proven. The thermal effects depend on the amount of electromagnetic energy applied to the tissues and are the basis of SWD therapy. The non-thermal effects, however,

are of interest and are still under investigation. It is accepted that the cell membrane is the main target for the EMF action, as it probably impacts on ion channels and signalling receptors located in the membrane. A number of studies are focusing on the effects of SWD affecting, signal transduction pathways and calcium ( $\text{Ca}^{2+}$ ) dependent signalling pathways (Nelson et al. (2013)) and also on their effects on the cell cycle (Zimmerman et al. (2012)). Calcium ( $\text{Ca}^{2+}$ ) acts as a secondary mediator in the cell signal transduction. It binds to calmodulin (CaM) and activates it. The activated CaM interacts with nitric oxide synthase (cNOS) leading to its activation (Pilla et al (2011)). Nitric oxide (NO) is a major signaling molecule that directly or indirectly affects a number of processes in the body. (Toledo et al. (2012)). The direct mechanism of action is associated with inflammatory reactions with the participation of CaM/cNOS/NO signaling pathways. Indirect mechanisms of action are associated with activation of adenylyl cyclase (AC) and soluble guanylyl cyclase (sGC). These enzymes affect the formation of cyclic adenosine monophosphate (cAMP) and cyclic guanosine monophosphate (cGMP). Thus, (via CaM/nNOS/cAMP signaling and/or CaM/NO/cGMP signaling) by affecting regulation, a change in a number of biological processes is observed, which may include inflammatory responses, cell specialization and/or programmed cell death, change in blood circulation and tissue restoration. (Pilla et al. (2011); Yu, Peng (2011)). Pilla et al. (2011), found that pulsed application of SWD (27.12 MHz for 30 min) resulted in significant increases in NO, cGMP and DNA levels in human articular chondrocytes. These changes can be blocked by CaM and NOS antagonists (Pilla et al. (2011)). Lekhraj et al. (2014) reported that a pulsed modulated ultrahigh-frequency electromagnetic field could affect the specialization and survival of MN9D cells from neural tissue. They attributed this effect of EMF to the involvement of CaM/nNOS/cAMP, suggesting that a NOS inhibitor could stop this process. Furthermore, CaM/cNOS/NO signaling may regulate interleukin (IL)-1 $\beta$  synthesis, which is associated with reduced inflammatory response and accelerated wound healing. According to Yu, Peng (2017), EMF can, due to the voltage-gated activity of  $\text{Ca}^{2+}$  channels, lead to a change and increasing the concentration of  $\text{Ca}^{2+}$  ions or calcium channels to alter  $\text{Ca}^{2+}$ -dependent signaling pathways. Another possible mechanism concerning the effects of EMF, according to Yu, Peng (2017), is also realized through a change in the cell cycle. It is known to be realized in four periods, has a phasic nature and involves various biological processes (DNA synthesis, chromosome division, etc.). Many factors of a chemical or physical nature, including EMFs, can induce changes in the cell cycle and/or lead to cell damage. EMFs can lead to significantly higher rates of DNA breakage in some cells- for example, sperm (Yu, Peng (2017)), indicating that very strict adherence to exposure dosages is necessary. The therapeutic effects are related to improving the elasticity of soft tissues, reducing muscle spasm and or spasticity, reducing pain in degenerative and traumatic processes, reducing edema, accelerating regeneration, and improving the trophic of peripheral nerves, influencing the inflammatory process. (Babaei-Ghazani A. et al. (2020); Benincá I.L. et al. (2021); Picelli A. et al. (2021); Munari D. et al. (2022); Almalty, A. R. et al.(2023)). The physiological and therapeutic effects of SWD, suggest the application of this type of therapy in diseases of different nature, and in the recent years literature a number of studies have been reported on the effect of therapy in patients who has suffered COVID-19 and post - COVID-19 syndrome.

**The aim** of this review is to provide an overview of the described therapeutic effects of the practical application of shortwave and ultrashortwave diathermy, including their potential applying in patients with COVID-19 or patients with symptoms of post-COVID-19 syndrome.

## 2. MATERIALS AND METHODS

For the purposes of this review, a search of currently published literature sources was conducted, which included: reports on the therapeutic application of high-frequency electromagnetic fields, overview articles, systematic reviews, and narrative synthesis regarding the application of short-wave and ultrashort-wave diathermy treatment. The study of scientific articles was carried out in the available databases Pub Med, Google Scholar, Elsevier. The search was conducted for the following keywords: physical therapy modalities, electrotherapy, electromagnetic therapy, diathermy (short-wave therapy), ultrashort-wave diathermy, radiofrequency therapy, deep heat, endogenous heat, inflammation, COVID-19, post-COVID-19 syndrome, reparation.

## 3. RESULTS

The review of the published scientific information on the therapeutic effects of high-frequency electromagnetic fields found evidence of anti-inflammatory, pain-reducing, trophic-enhancing and tissue regeneration effects of diathermy in various diseases, including lung diseases and including patients with COVID-19, post-COVID-19 syndrome. However, other authors think that there is currently insufficient information on the efficiency, methods of administration, dosage and safety of high-frequency electromagnetic fields, and more studies are necessary regarding their use in patients with COVID-19.

#### 4. DISCUSSIONS

SWD and Microwave diathermy (MWD) are applied to a wide range of diseases. They are an effective therapy for skeletal muscle and tendon injuries (Giombini et al. (2007)). The efficacy of diathermy is related to the increase of heat in deep tissues. The effect includes increasing vasodilation and elasticity of soft tissues, improving local blood flow and reducing muscle spasms (Frasca et al. (2011); Ozcete et al. (2013); Boyaci et al. (2014); Incebiyik S. et al. (2015)). Furthermore, diathermy (27.12 MHz) was found to improve distal motor and sensory latencies (Ozcete et al. (2013); Incebiyik et al. (2015)), and nerve conduction velocity of n. medianus in patients with carpal tunnel syndrome (Boyaci et al. (2014)), whereas diathermy at 434 MHz resulted in no change in these electrodiagnostic parameters (Frasca et al. (2011)). Although carpal tunnel syndrome is often of ideopathic etiology, it is associated with diabetes mellitus, rheumatoid arthritis, hypothyroidism, pregnancy, and tenosynovitis (Incebiyik et al. (2015)). This also determines different pathophysiological mechanisms of injury as opposed to traumatic peripheral nerve injury (Fu et al. (2019)). In another study, Boyaci et al. found that SWD, or Microwave Diathermy (MWD), can reduce pain and improve function in patients with carpal tunnel syndrome (Boyaci A. et al. (2014)). In a non-systematic review, Fu et al. (2019) reported that EMFs can improve the repair of damaged peripheral nerve by increasing myelinated fibers, increasing the thickness of the myelin sheath and the diametrical circumference of the axon. In experimental conditions, they observed the listed effects by applying SWD (27.12 MHz) and MWD.

Moreover, electrophysiological parameters and locomotion also improved, indicating that SWD or MWD, can accelerate nerve regeneration (Fu T. et al. (2019)). When the peripheral nervous system is damaged, proliferation and differentiation of Schwann cells occurs, whereby they are actively involved in the repair processes (Scheib, Hoke (2013)). This leads to the expression of genes associated with regeneration, including those encoding neurotrophic factors such as brain-derived neurotrophic factor (BDNF), nerve growth factors, glial neurotrophic factor and pleiotrophin (Gordon, English (2016)). SWD increases BDNF expression in spinal cord and muscle (Pang et al. (2013)), suggesting that BDNF expression may be involved in the regeneration process of nerves treated with shortwave diathermy. Other authors have reported that SWD can stimulate peripheral nerve regeneration by upregulating vascular endothelial growth factor (VEGF) iRNA expression in spinal cord and muscle in the tarsal zone (Zhang et al. (2008); Pang (2013)). VEGF enhances angiogenesis, enhances Schwann cell proliferation and migration, and plays an important role in peripheral nerve regeneration (Hobson et al. (2000)).

There are numerous scientific reports and studies that show a positive effect of SWD in patients with chronic non-specific low back pain (Karasel et al. (2021); Wittenwiler et al. (2018); Paladini et al. (2020)) It is commonly used, in patients with pain and in various degenerative joint disorders including knee joint pain and gonarthrosis (Nelson et al. (2013); Ozen et al. (2019)). SWD has been successfully applied in clinical practice to accelerate reparative processes in wound healing (Yu, Peng (2017)). Strauch et al. (2007) found that pulsed high-frequency electromagnetic field (HFEMF) without thermal effect improved skin wound repair in experimental models (Strauch B. et al. (2007)). Another advantage of pulsed diathermy is to reduce the inflammatory response and improve the rate of tissue repair by suppressing the release of inflammatory factors (cytokines) (Rasouli et al. (2012); Kubat et al. (2015); Munabi et al. (2015)). In another double-blind, placebo-controlled, randomized study, Munabi et al. (2015) administered pulsed field SWD to patients after surgical treatment, with one group receiving pulsed SWD and the other placebo. They found a more than twofold reduction in IL-1 $\alpha$  and IL-1 $\beta$  in the wound exudations of the treatment group after a 1-h exposure to a 27.12 MHz pulsed SWD compared to placebo, indicating a reduced inflammatory reaction in the pulsed SWD-treated group (Munabi et al. (2015)).

In practice, SWD has been successfully applied to reduce postoperative pain among other physical factors, resulting in a reduction in the use of pharmacological agents for pain control. In a study Rawe IM. et al. (2012), applied SWD (27.12 MHz, 1000 pulses/s and pulse duration of 100 $\mu$ s, at peak pulse power of 9.8 mW, over an area of 100 cm<sup>2</sup> for 20 minutes) by measuring pain on a visual analog scale (VAS) every 4 hours, on the first and third postoperative days. They found a significantly lower level of pain in the pulsed VAS-treated group compared with placebo. The therapeutic effect achieved was probably due to the reduced inflammatory response and improved microcirculation (Rohde et al. (2010)).

Ultrahigh-frequency currents are traditionally used in Physical Medicine to affect local inflammatory processes (Laufer et al. (2012)) and lung inflammation (Zhang et al. (2003); Yu HP. et al. (2020)). In relation to the pandemic of COVID-19 that has developed, which primarily affects the respiratory system of patients with acute infection, and the available data on residual physical and functional impairment after hospitalization, and recovery from COVID-19, (Baricich et al. (2021)) and the search for appropriate therapeutic strategies, and adjuvant treatment, and existing scientific evidence on the possible therapeutic effects of SWD administration in patients with inflammatory diseases of the respiratory system Tian et al. (2022) conducted a prospective, double-blind, randomized controlled clinical trial of patients hospitalized with COVID-19. The study included 42 patients with moderate COVID-19 randomly assigned to two groups. The first group underwent SWD (27.12MHz; 10 min), electrodes were placed dorso-

sternally in the upper chest, a treatment course of 14 days in addition to standard therapy and a control group with standard therapy and placebo SWD. They found a clinical improvement in 92.6% of patients in the SWD group by the 14th day identified, by a two-step decrease in a seven-point ordinal rating scale (according to Wang Y. et al. (2019)) compared to 69.2% of patients in the control group. The other index tracked was lung CTA. The other index tracked was lung CAT. It was assessed by the integrated improvement rate on lung CAT. Scans were performed at baseline and again on day 14 and were assessed according to the classification of Zheng et al. (2020). The authors observed improvement in CTA in 85.2% of patients in the SWD group, compared with 46.2% in the control group, by day fourteen. They did not observe the side effects described in other studies, such as chest pain, cardiac arrhythmia, burns, and pulmonary fibrosis (Yu et al. (2017)). Only headache was recorded in two patients in the treatment group (7.4%) and one in the control group (7.7%), and vertigo in one patient in the treatment group (3.7%) (Tian et al. (2022)).

The therapeutic effects achieved, including both a significantly shorter time to reverse clinical manifestations and the recorded improvements in COVID-19 patients in the - SWD group, compared to the control group, were attributed by the authors to the generally accepted effects of SWD based on an increase in blood current in the area between the two electrodes, resulting in anti-inflammatory and analgesic effects (Tian et al. (2022)). Similar effects have been confirmed in other lung diseases, such as severe acute respiratory syndrome (Zhang et al. (2003)), bronchopneumonia (He YG. et al. (2006)), spontaneous pneumothorax (Ma et al. (1997)), and chronic obstructive pulmonary disease (Wang et al. (2003); Zhang et al. (2007)).

In another preliminary report, Liangjiang Huang et al. (2021) reported a single-center, randomized, controlled clinical study to evaluate the side effects and effectiveness of SWD in COVID-19 patients. The study enrolled 50 COVID-19 patients with moderate to severe form. They were randomized into two groups. The test group conducted SWD (27.12MHz) in addition to the standard care for 10 minutes, twice daily for 12 consecutive days, and the control group conducted standard medical treatment. The authors recorded a significantly reduced clinical recovery time in the patients of the test group compared to those of the control group. At the same time, the authors assumed that the therapeutic effect was not directly dependent on antiviral activity of SWD. In the study, no adverse events or worsening of pulmonary fibrosis were observed in the SWD group (Liangjiang Huang et al. (2021)).

In a recent scientific publication, Wu et al. (2022) reported positive effects of HFEMFs administration on animal models with induced acute lung injury (Wu Q. et al. (2022)). This acute respiratory distress syndrome (ARDS) is characterized by neutrophil leukocyte accumulation, interstitial tissue edema, and lung alveolar epithelial damage (Mowery et al. (2020)) due to an overactive lung inflammatory response, development of oxidative stress, manifestations of hyperinflammation and a "cytokine storm" picture (Kellner et al. (2017)). According to previous publications, SWD, can reduce inflammatory activity and would be an appropriate adjuvant therapy (Yu HP. et al. (2020)). The ability of cells to absorb energy from oscillating electric fields of defined frequencies and/or amplitudes may explain the physiological effects of SWD. These effects include improvement of local blood circulation, impact on pain, reduction of inflammation, tissue swelling and stiffness, tissue regeneration in wound defects (Wang N. et al. (2018)).

Wu et al. (2022) applied USWD (ultrashort wave therapy) at a frequency of 40.68 MHz for 15 min at the earliest after 4 h and then after 8 h after induced acute lung injury in animals. They use two disk-shaped electrodes placed 2 centimeters from the surface of the skin. They randomized the experiment into two groups: a group with electromagnetic field application and one without treatment. The authors reported that the application of high-frequency electromagnetic therapy significantly reduced IL-1 $\beta$  and TNF $\alpha$ , confirming the anti-inflammatory effects of EMFs in acute lung injury. In addition, EMFs decreased malondialdehyde (MDA) levels and increased superoxide dismutase (SOD) and glutathione peroxidase 4 (GPx4) levels. Possibly through this mechanism, EMF can reduce lung tissue damage by affecting oxidative stress and reducing inflammation in animal models of induced acute lung injury. Based on the obtained results, they assume that USWD may be a promising adjunctive treatment to counteract oxidative stress and inflammatory activity and possibly a positive option for the therapy of patients with acute lung pathology (Wu Q. et al. (2022)). However, other authors believe that currently the information is insufficient regarding the efficacy, methods of administration, dosage and safety of electromagnetic fields, and more studies need to be conducted regarding the use of UHF in patients with COVID-19 (Yu et al. (2020)).

## 5. CONCLUSIONS

The use of short- wave and ultrashort-wave diathermy is associated with potential therapeutic benefits. Anti-inflammatory, pain-reducing effects, improving regeneration, trophicity and tissue elasticity capabilities of this therapy have been described, including in COVID-19 survivors. On the other hand, due to the possibility of tissue injury from high-frequency electromagnetic fields, it is necessary to rigorously refine the need for their administration.

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