Chapter

Use of an Evolution in Tecartherapy for Muscle Improvement and Treatment of Sports Injuries

Jesús Clemente Rodríguez Lastra and Ester Piñero Mendez

Abstract

Radiofrequency assisted medical devices have evolved dramatically in the last two decades, such that a simple set of fairly basic tools has now become an extremely sophisticated option. Most importantly, a physician's understanding of these devices can maximize treatment results. Diathermy, meaning "through heat," consists in the application of short-wave electromagnetic energy. The factor that determines whether a diathermy machine will increase body temperature is the amount of energy absorbed by the tissue. The development of this device allows selecting the frequency to apply between 0.8 1 and 1.2 MHz; the application of high energy power, through several channels and increasing the treatment area, allows taking the radiofrequency to another level in rehabilitation sports medicine. RF is applied to the target area by a handpiece that delivers energy, while a grounding pad is placed elsewhere on the body for the energy to pass through. The entry of RF into the body at the site of contact with the active electrode leads to heating a volume of tissue. This ability to heat a volume of tissue in a non-invasive way produces the immediate contraction of collagen, and the delayed synthesis of collagen, by thermal induction fibroblasts, and the production of epithelial, vascular growth factors. RF has a firm, safe and increasingly popular place in the therapeutic arsenal of sports medicine.

Keywords: sport Injury, radiofrequency Capenergy, Tecartherapy, cellular effects, pain, rehabilitation

1. Introduction

Diathermy treatment has long been used in the recovery of sports injuries, the term itself refers to heat, as the most important effect of the treatment. The movements of water molecules by the effect of electromagnetic waves, produce heat. But today it is known that molecular effects, especially in the cell membrane, produce the movement of ions, which function as signals for the immune response. The increased production of both epithelial and vascular growth factors, which improve healing and produce angiogenesis, increasing blood circulation, have given a new perspective to this treatment. Where, selecting the appropriate frequency, the highest energy power, expanding the treatment area and the possibility of recognizing the penetration of the energy in the tissue, gives a new perspective to the treatment of Tecartherapy, for the athlete's injuries. The effects of RF are detailed below. The objective of this Chapter is then to put in the hands of Physicians, Rehabilitators and Physiotherapists the current knowledge of the effects of the new RF equipment for the treatment of sports injuries.

Diathermy, a Greek word that means "through heat", consists of the application of short or long-wave electromagnetic energy. This wave radiation is in the radiofrequency (RF) range (3 kHz to 300 MHz frequency and 1 m to 100 km of wavelength). The use of diathermy dates back to 1892, when d'Arsonval used radio frequency electromagnetic fields with a 10 kHz frequency to produce a warm sensation without muscle contractions, that take place at a lower frequency [1] (Culotta 1970).

The most important factor that determines whether a diathermy device will increase body temperature is the amount of energy absorbed by the tissue. This is determined by the intensity of the electromagnetic field produced by the device and by the type of tissue in which it is applied. However, there are more factors that contribute to the penetration of energy in the body that we will evaluate below.

We will first describe the electromagnetic field. An electromagnetic field is the force field created around an electric current that is made up of an electric field and a magnetic field. Both electric and magnetic fields are produced when a charged particle moves at a constant speed. EMFs (Electro Magnetic Fields) are generated when the charged particle accelerates and increases in speed. Very often, this acceleration takes place in the form of an oscillation, therefore the electric and magnetic fields are oscillating.

The objective of this Chapter is to put in the hands of Physicians, Rehabilitators and Physiotherapists the current knowledge, of the effects of the new RF equipment for the treatment of sports injuries. This chapter will develop the basic concepts of innovative RF technology with the intention of minimizing the inflammatory and pain effects, that many musculoskeletal injuries cause, as well as, ensuring that tissue regeneration is done through total recovery from injury and that the recovery time is minimized. These concepts will be developed in detail in the next few lines.

2. Frequency

Frequency is the wavelength of the oscillation. Different frequencies are used in diathermy. As tissue absorption increases with frequency, it is often assumed that lower frequencies, on the order of MHz, result in better transfer efficiency. But it has been pointed out that the frequency of 1 MHz is the one that manages to overcome the resistance of the cell membrane and produce the intracellular effects that we will see later [2] (Ivorra 2002).

3. Power

One of the fundamental components of electromagnetic fields is power or energy. Electromagnetic waves provide energy to a system by virtue of their electric and magnetic fields. These fields can exert forces and move charges in the system and, therefore, work on them. However, there is energy in an electromagnetic wave itself, whether it is absorbed or not. Once created, the fields carry energy from a source. If some energy is then absorbed, the intensity of the field decreases. Clearly, the greater the strength of the electric and magnetic fields, the more work they can do and the greater the energy carried by the electromagnetic wave. In electromagnetic waves, the amplitude is the maximum field strength of the electric and magnetic fields. The energy of the waves is determined by the amplitude of the waves. The energy carried by a wave depends on its amplitude [3] (Ling et Al 2019).

4. Energy coupling

The water in the tissues is the fundamental cause of energy absorption in the human body: the more liquid accumulates in an area, the more energy is absorbed [4] (Romanenko et Al 2017). Being able to recognize the amount of energy that penetrates allows you to locate the area of inflammation. When the radio frequency wave penetrates the tissue, it moves water molecules. Remember that water molecules are a dipole, hence they vibrate with the waves as shown in **Figure 1**.

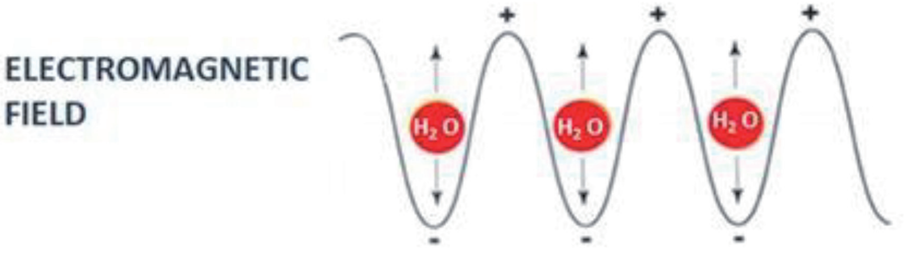

Figure 1.
Movement of water molecules due to radiofrequency oscillations.

5. Capacitive and resistive electrodes

The capacitive electrode is covered by an insulator. Imagine a capacitor formed on one side by the capacitive electrode, and on the other, a resistive conductor formed by the biological tissue and another metallic conductor (return plate) that closes the circuit. The capacitive conductor is made up of metal compounds and alloys. The application of a capacitive conductor is characterized by displacement currents instead of conduction, and the charged particles tend to have a higher charge density in the vicinity of the dielectric, act on the most superficial tissues (first 3 cm) rich in water and its energy tends to progressively increase from the return plate to the capacitive electrode with the consequent increase in temperature of the tissues.

In resistive mode, the electrode is conductive, metallic and is applied directly to the body. The current passes through the sector of the body where it is applied, dispersing towards the return electrode. During this process, heat is generated due to the energy delivery in the tissue and the resistance that the tissues oppose to its passage. The concentration of charges, and therefore the biological effect, occurs at the points of greatest resistance of the current, such as the bone tissue, which is located between the active electrode and the return electrode. But other highly resistant tissues due to their low water content such as tendons, ligaments and bands of muscles and tendons will have also biological effect. In this way, a charge displacement current is created within the biological tissue that determines the involvement of the deep layers and the consequent homogeneity of the endothermic response with greater depth. The plate electrodes are 200 m^2 capacitive electrodes (**Figure 2**).

The more area of application, the more energy is delivered. A larger area allows the penetration of the energy to be more extensive and the effects more extensive in the area of the injury and the surrounding tissues.

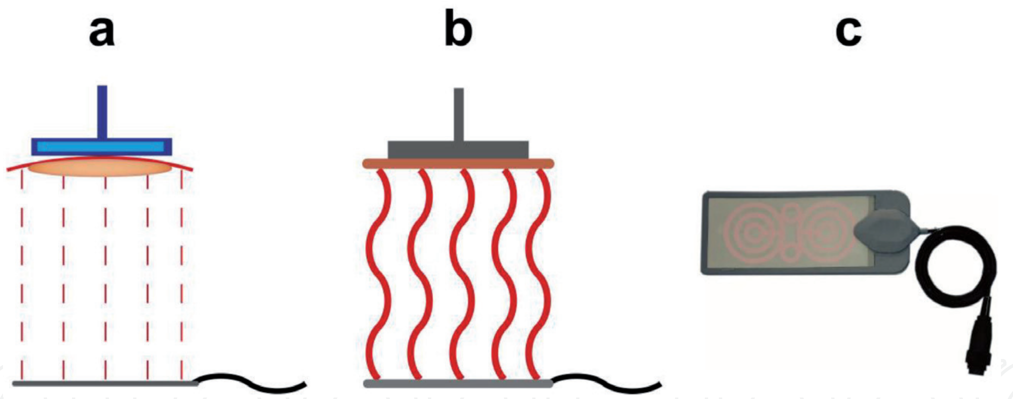

Figure 2.
Electrodes, resistive (a) capacitive (b) and capacitive plate of 200 cm^2.

6. Energy channels

Being able to increase the amount of energy by incorporating more channels to the treatment, first of all allows incorporating a larger area of application, covering more space around the lesion, and can be used simultaneously with physical activity, on the one hand. Moreover, the.

capacitive and resistive electrode can also be used simultaneously. An energy summation occurs where in the most superficial area the energy load is greater.

7. Thermal and athermal effects

Heat is generated in the tissue both by the electrical process and by the magnetic field. The static magnetic field cannot heat the human body as it does not transfer any net energy, so it does not produce heat. Therefore, the tissue heating mechanism is by electric current and is based on the generation of joules of heat. The heat generated is described by Joule's Law:

$$E = \frac{j^2}{\sigma} \quad (1)$$

Where E is the energy, j is the density of the electric current and σ is the electrical conductivity. The conductivity is 1 / R (R = resistance).

The absorption of electromagnetic energy by the tissues of the human body is complicated because there are different types of tissues, with different coefficients of conductivity. As the depth of penetration into the tissues increases, the frequencies change, such that most of the incident energy can be transmitted at one frequency, but absorbed at another. The depth of penetration per frequency depends on several factors: dry skin, infiltrated fat, and muscle, calculated according to the characteristics of the Gabriel model.

All mechanisms that cannot induce a temperature increase greater than 0.010 ° C (when we consider a system as a living organism), less than 0.001 ° C (when a system is considered as a cell), or again less than 0.0005 °C are considered non-thermal, when studying a sub-cellular system.

At present, there is a controversy between the thermal sensation of the patient and the application of energy. Hence the term athermic, as the temperature in the tissue does not increase. The real connotation of athermic is that the patient does not perceive the increase in temperature. The patient has little thermal sensation, since it is an application with little energy. Due to the fact that energy is introduced into the tissue, it causes the water molecules to vibrate and this produces heat.

8. Temperature or biological effects

The term diathermy already suggests that temperature is the main effect of electromagnetic waves in the body. But the cellular signaling effects that are produced are very important for the resolution of the lesions. We will now see the effects of temperature on tissues and electromagnetic energy on the cell. A general summary of biological effects is presented in **Figure 3**.

8.1 Heat and hyperthermia

Heat treatment in mammalian cells at temperatures above 40 °C produces multiple effects on cell metabolism. Hyperthermia inhibits protein synthesis. It induces the production of heat shock proteins and inhibits energy metabolism. At temperatures in the range of 50–60 °C it damages DNA and denatures it and at temperatures below 40–46 °C it produces chromosomal aberrations if the cell is in the S phase of mitosis.

An important role in this response is played by the Thermal Shock proteins (HSP), a superfamily of proteins highly conserved in evolution, which play an essential role in the conformational and functional protection of proteins within the cell. With molecular weights of 72 kDa, 73 kDa and 90 kDa they correspond to the largest classes of stress proteins expressed by the body.

Another effect of warming is the local effect. In general, the therapeutic range for sports medicine is assumed to be 41–45 °C, because this range causes the maximum increase in local blood flow [5] (Perez y Al 1993). Therefore, hyperthermia treatment is considered to provide effective therapeutic conditions. On the contrary, from a safety perspective, the possibility that treatment above 45 °C causes muscle damage cannot be ignored. The duration of heat treatment is also a concern in hyperthermia therapy. For example, in oncology, patients receive hyperthermia therapy at 45 ° C for 15 minutes if they do not feel pain. In short exposures 1–2 minutes of duration, temperatures of >45 °C can be reached, without the treatment causing damage to muscle tissue.

Concluding hyperthermia acts by producing an increase in heat shock proteins and increasing local blood flow.

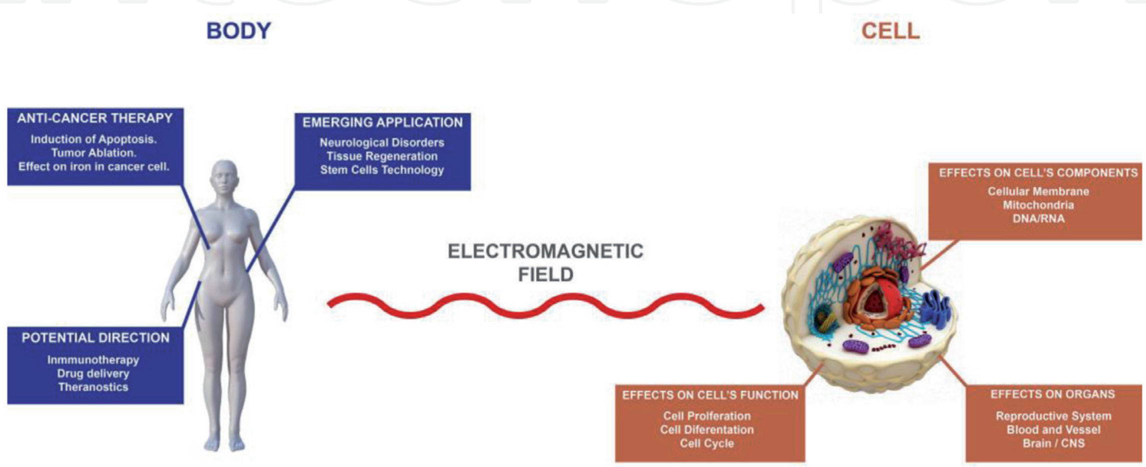

Figure 3.
Effect of the electromagnetic field on the cell and the body.

8.2 Effect on cells

Cells interact with their environment through the cell membrane. Among other functions, the cell membrane is responsible for the detection and subsequent transduction of external biochemical or other signals in the cytoplasmic space. The cell membrane is also considered the main site of interaction of EMF signals with cell systems.

A large body of literature has shown that various biological RF (Radio Frequency) effects can be produced without tissue heating, which are known as non-thermal biological effects of electromagnetic radiation.

The cell membrane is a 5–10 nm thick structure that surrounds and encloses the cell. It is made up of lipid and protein molecules. The most abundant membrane lipids are called phospholipids. The cell membrane is a lipid bilayer that allows the flow of ions through proteins that function as channels and ionic pumps. Ion flow can be stimulated with an external stimulus, to activate specific signaling pathways intracellularly. Although studies have applied electrical and magnetic stimuli to modify cell function, the parameters for stimulating the cell membrane are unknown.

The effects of exposure to an electromagnetic field can be understood as a chain of responses at different interrelated scales in the biological system. This chain of events begins with the interaction between the incoming wave and the charged atomic structure of biomolecules, mainly ions, especially outside the cell. This interaction leads to changes in the chemical composition and charge distribution of proteins and other macromolecules that are transduced into changes in biochemical signaling pathways.

8.3 Effects on calcium

Exposure to EMFs may act to cause excessive Voltage Dependent Calcium Channels (VGCC) activity in many cell types, suggesting that these may be direct targets of EMF exposure. Many of these studies specifically implicate L-type VGCCs, such that various L-type calcium channel blockers may block responses to EMF exposure. Stimulation of VGCC by the electromagnetic wave leads to an increase in intracellular Ca^{2+}, which can act in turn to stimulate the two calcium / calmodulin-dependent nitric oxide synthases and increase nitric oxide [6] (Wooda and Karipidisb 2021). This nitric oxide acts in therapeutic or potentially therapeutic responses of EMF, through its main physiological pathway, stimulating Guanosine Monophosphate cyclic (cGMP) and protein kinase G. Nitric oxide can act in pathophysiological responses to exposure to EMF, acting as a precursor of peroxynitrite, with its dual role, producing both oxidative stress and free radical decomposition products (**Figure 4**).

For lymphocytes, Ca^{2+} mobilization is among the first detectable events to be triggered by binding of a ligand (e.g., Antigen, receptor antibody, mitogenic lectin) to an appropriate receptor structure exposed on the outer cell surface. The cascade of cellular reactions in lymphoid cells subsequent to ligand-receptor interaction is best understood for T cells and has been extensively reviewed. In summary, ligand-induced Ca^{2+} mobilization is reflected in an initial increase in Ca^{2+} that is caused by inositol 1,4,5-triphosphate-induced Ca^{2+} release from intracellular stores and followed by a sustained influx of Ca^{2+} mediated by receptors from the extracellular environment, including cell proliferation, secretion, motility, etc. or cytotoxicity. With regard to the effects of electromagnetic fields on the immune system, it is proposed that Ca^{2+} regulation in lymphoid cells could be similarly affected by appropriate signals from electromagnetic fields, leading to informed responses of electromagnetic fields. In cells, for example, on proliferation or cell-mediated cytotoxic agents [7] (Pall 2013).

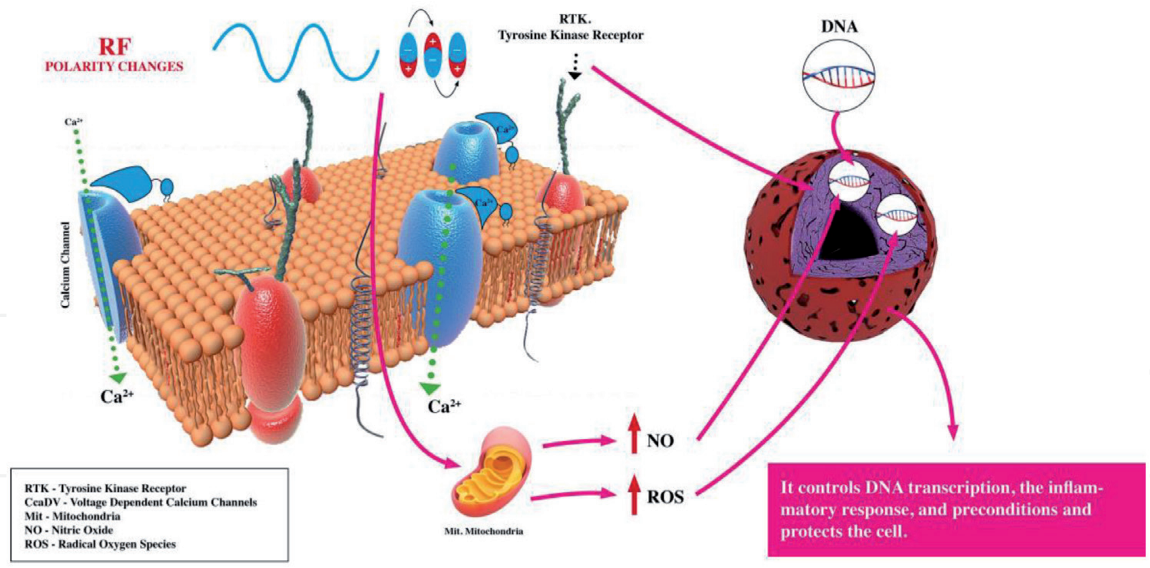

Figure 4.
Mobilization of intracellular calcium after opening the voltage-dependent calcium channels by electromagnetic energy.

Cellular Ca^{2+} mobilization in response to external EMF signals or interference of an EMF with Ca^{2+} regulatory processes is considered an important target of EMF action in tissues.

8.4 Effect on fibroblasts

Fibroblast is a type of cell that synthesizes the extracellular matrix and collagen, the structural framework of animal and human tissues, and plays a critical role in wound healing. Fibroblasts are the most common connective tissue cells in animals. The main function of fibroblasts is to maintain the structural integrity of connective tissues through the continuous secretion of precursors from the extracellular matrix, and as a result, this type of cell is critically involved in the wound healing process [8] (Aaron et Al 2013).

EMFs are known to play an important role in the cascade of processes that determine cell migration, adhesion, and differentiation. Electric currents and related

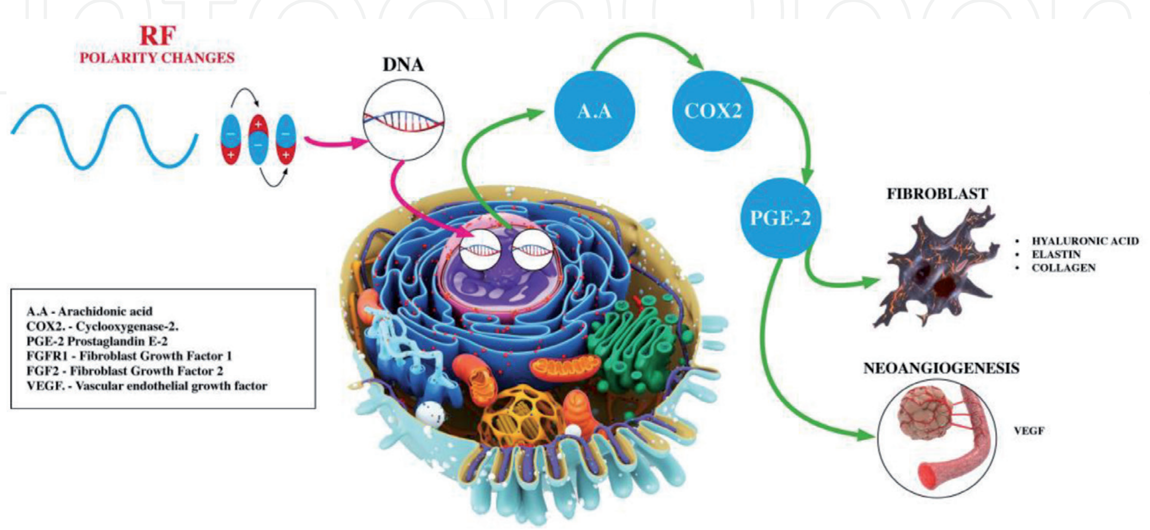

Figure 5.
Intracellular signaling and stimulation of fibroblasts increasing the levels of both epithelial and angiogenic growth factors.

fields are generated by passive absorption of Na^+ from the environment, leading to an internally positive transepithelial potential difference.

EMF can activate fibroblast migration. EMF has been shown to activate fibroblast proliferation. Activation of the expression of human fibroblast growth factor 1 (HFGF1), after exposure to EMF, showed that molecular wound healing pathways are activated in response to this resonant EMF in water (**Figure 5**).

For this reason, the application of EMF may have therapeutic relevance for wound healing and other pathologies.

9. Repair of collagen, hyaluronic acid and bone production

Collagen is considered to be one of the most important biomaterials in cartilage repair. We have shown that exposure to pulsed radiofrequency, that is, with more energy and little heat, improves chondrogenic differentiation and protein synthesis of the extracellular matrix of cartilage. Collagens are proteins composed of three polypeptide subunits known as α chains that exist in a single triple helix. There are more than 20 types of collagen in animal tissue. Scientific research has confirmed the activity of EMFs (electromagnetic fields) in this tissue [9] (De Mattei et al. 2007). In vitro and in vivo studies have shown that EMF can change some physiological parameters of bone cells, such as proliferation [10] (De Mattei et al. 1999), differentiation [11] (Lohmann et Al 2000), synthesis of extracellular matrix components [11–13] (Lohmann et Al 2000, Heermeier et Al 1998, Harting et Al 2000) and production of growth factors. In addition, EMFs can stimulate osteogenesis in bone. This has been shown in many studies [14] (Thamsborg et Al 2005).

Clinical studies demonstrated that EMF exposure could be useful for the treatment of degenerative cartilage disorders such as osteoarthritis. Several studies have investigated the effects of electromagnetic fields on cartilage cells and tissue, showing that electromagnetic fields can stimulate chondrocyte proliferation and increase the amount of ECM (extracellular matrix) components of cartilage. EMFs stimulate proteoglycan (PG) synthesis in vivo and in vitro. TrPs are critical components of the cartilage, and loss of TrP from tissue is seen in OA. EMF can stimulate the synthesis of PG [15] (Goldring 2000).

Electromagnetic fields have positive effects on bone and cartilage tissue. Electromagnetic fields affect the mobility of K, Ca^{2+}, Mg ions in bone and cartilage. They increase collagen synthesis [12] (Heermeier at Al 1998).

9.1 Angiogenesis

There is evidence to support the concept that radiofrequency acts by promoting angiogenesis through the coordinated release of fibroblast growth factor β-2 FGF-2 and, to a lesser extent, various other vascular growth factors angiopoietin-2 (Ang-2), thrombopoietin (TPO) and epidermal growth factor (EGF). This suggests that RF may facilitate healing by increasing blood vessel growth. This finding not only clarifies a novel mechanism for the action of RF, but also suggests widespread applications in the treatment of ischemic disease and a potential link between electromagnetic fields and increased tissue circulation.

9.2 Lymphatic drainage

When a sports injury occurs, the injury site reaction is inflammation, which is accompanied by edema. The phases of inflammation are, in order: organization of the hematoma, necrosis and finally, degeneration of the muscle fibers with

Figure 6.
Lymphatic drainage in the lower limb: The active plate, which delivers the energy, is placed on the sole and the passive plate, that takes it to the ground, is placed in the lumbar area. Lymph moves from one plate to the other.

diapedesis of macrophages and phagocytosis towards the necrotic material. After increased blood flow by the action of temperature and EMF, waste substances accumulate in the area of injury and surrounding areas (**Figure 6**).

Magnetic field interactions with blood flow have been demonstrated. In addition to this, electrically charged proteins also move between the electric poles. An approximately linear growth of the flow rate of water with an electric field intensity has been studied.

The magnetohydrodynamic law explains that the force experienced by an enclosed charge moves fluids. Erythrocytes and proteins have charge and these elements are inside the blood vessels. The RF energy acts on these elements according to this law, and moves the fluids in the body with a speed under an applied electric field. The blood, as the most abundant fluid in the body, will act as a fluid conductor necessary to conduct the energy, as it increases its flow. It has been suggested that the magnetic characteristics of the blood can be used to improve the hemodynamic disturbances associated with atherosclerosis.

The elimination of the substances, which accumulate during inflammation, is achieved by performing a lymphatic drainage: the active plate is placed on the feet or hands and the passive plate in the lumbar area. The movement of blood and the lymph drags the waste substances towards the chest area to join the thoracic duct and circulation [16] (Cau et Al 2019).

10. Effect on sports pathology

10.1 Effect on the muscles

In sports medicine, diathermy devices for musculoskeletal use have been identified by the term "Tecartherapy". Tecartherapy stands for Transference of Capacitive and Resistive Energy. The Tecartherapy intervention improves the spatio-temporal biomechanical parameters in runners. A study by Duñabeitia in 2018 [17], indicates that the application of capacitive and resistive RF after an exhaustive training session, rather than passive rest, generates a more efficient running pattern, even though selected physiological parameter markers are not affected. These findings highlight the potential role of Tecartherapy in accelerating recovery from muscle fatigue in runners, which could lead to better performance. Differences were detected in the length of the step and the angle of the stride, the height and the frequency between the group of treatment with Tecartherapy and the control group, with an increase of these (**Figure 7**).

10.2 Pain

RF procedures in chronic pain utilize alternating current in the AM RF band to produce effects on pain pathways [18] (Rea et Al 2011). In 2020 Bretelle y Col [19]

Figure 7.
The active plates can be used during physical exercise, which improves muscle performance.

publish a Clinical Trial, where they report that RF treatment, showed a significant reduction in perineal discomfort while walking and could halve the use of analgesics, which could improve well-being during this sensitive period. RF treatment showed a significant reduction in perineal discomfort while walking and could halve the use of analgesics, which could improve well-being during this sensitive period. Musculoskeletal diseases comprise several conditions that are characterized by pain and limitations in mobility, dexterity, and functional capacity, reducing people's ability to work and participate in social roles with associated impacts on mental well-being. Some of the most common and disabling musculoskeletal diseases are osteoarthritis, back and neck pain, tendinopathy, fibromyalgia, and myofascial pain. Also, muscle injuries are the most common category of injuries in athletes and comprise approximately 10% to 55% of all injuries. Most muscle injuries (> 90%) are contusions or strains, while lacerations are much less common. The most serious types of musculoskeletal diseases can cause chronic pain, dysfunction, recurrence, and even compartment syndrome. Studies are in development with partial results. They have shown that these latest generation radiofrequency devices reduce the recovery time from injuries, by increasing blood flow, signaling, and especially by lymphatic drainage [20] (Tramuntana 2020).

Calcium/calmodulin-dependent kinase II (CaMKII) signaling is essential to maintain aberrant hyperexcitability of the dorsal horn neuron in the pain condition. RF signals have been shown to modulate CaM-dependent signaling pathways that orchestrate the release of cytokines and growth factors in cellular responses to injury. RF signals have been shown to modulate CaM-dependent NO signaling cascades in articular chondrocytes [21] (Pilla et Al 2011) and other cells using CaM antagonists, and NO downstream inhibitory.

10.3 Trigger points

Trigger points are specific sensitive areas in a muscle. They are part of a condition called myofascial pain syndrome, which involves muscle stiffness, tenderness, and pain that radiates to other areas, also known as referred pain [22] (Melzack et al., 1997). The term "myofascial" has evolved from the perspective that it is likely that both muscle and fascia may be contributors to symptoms [23] (Akamatsu et al.). Trigger points arise from the clustering of sodium-sensitive sites. In fact, the excitation processes of cells involve the entry of sodium through the membrane of the muscle fibers. Therefore, it is thought that most, if not all, pain points will be associated with sodium-sensitive sites.

The effects of magnetic, electric and electromagnetic fields on sodium / potassium ATP-handle have been studied extensively over the last quarter of a century by various researchers, but the most important for trigger points are the studies conducted by https://www.mendeley.com/download-desktop-new/, in addition to the Na ion transport mechanism, by K-ATPase, EMF interactions with transient electrons and protons that are released from the oscillating motion that affects the bonds of hydrogen (H) in hydrated proteins which could be involved in the mechanism of action. It is highly probable that the hydrogen bonding of water molecules with ions / ligands could be a hypothesis, for understanding the effects of magnetic fields on pain relief. Therefore, it would be logical to transfer these interactions to the discussion of trigger points as an acceptable mechanism for pain relief in myofascial pain [24] (Blank 2005) (**Figure 8**).

There is a study with patients with trigger points that prevented them from carrying out their daily activities and where capacitive radiofrequency (C-RF) was applied. The results found proved that C-RF is an effective solution to treat painful conditions with a limiting factor for daily activities.

10.4 Muscle injuries

After a muscle injury secondary to trauma, there is a rupture of blood vessels, bleeding at the injury site, and subsequent edema. Direct trauma to muscle fibers also causes rupture of the basal lamina and sarcolemma and subsequent degeneration of the sarcomeres in the affected area [25] (Hazlewood and Markov 2007). Diathermy produces a much faster increase in soft tissue temperature. Associated with the increase in tissue temperature there is an increase in blood flow. Elevated tissue temperatures improve blood flow and can relieve muscle spasms and pain [26] Karpati et Al 1982), and improve recovery from injury.

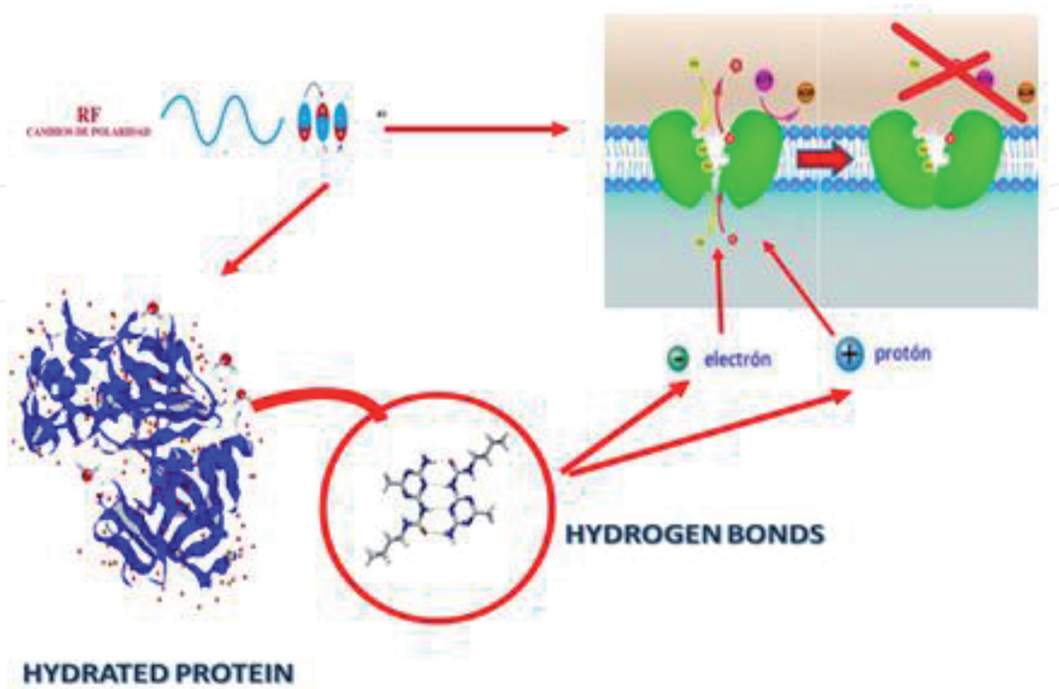

Figure 8.
Effect of electromagnetic energy on Na / K ATP ASA. Hydrogen bonds in protein release electrons and protons, which block the pump proteins.

10.5 Cartilage injuries

The use of RF for the treatment of injured cartilage has increased enormously in recent years. The safety and effectiveness of this technique depend on an understanding of the physics behind RF. First, it is not electrocautery. During application, a high frequency alternating current flows from the uninsulated probe tip into the tissue. Ionic agitation occurs in tissue when the ions try to follow the directional changes of the alternating current. This agitation produces frictional heating so that the tissue around the electrode tip, rather than the electrode plate itself, is the main source of heat. The heat produced during the application of RF is the difference between the heat generated by the flow of RF current through the tissue surrounding the probe tip and the heat that is dissipated in this region [27] (Ryland et Al 2001).

10.6 Urinary incontinence in female athletes

Urinary incontinence (UI) is defined as the involuntary loss of urine. When pressure inside the abdomen increases due to exertion, it is transmitted to the bladder causing the pressure within the bladder to be higher than in the urethra. For proper function of urination and urinary continence, intraurethral pressure must be higher than intravesical pressure both at rest and in activities that require effort. There is pelvic floor dysfunction in high-performance athletes associated with athletic activity and urinary incontinence. Eating disorders, constipation, family history of urinary incontinence, history of urinary tract infections and decreased flexibility of the plantar arch are associated with an increased risk of UI in elite female athletes. Pelvic floor physiotherapy as a treatment for urinary incontinence in elite female athletes, former elite female athletes and pregnant athletes who engage in regular aerobic activity leads to a higher continence gain than that obtained by nonathlete women [28] (Thyssen et al., 2002).

The use of radiofrequency with high power, which is a diathermic process generated by the radiation of an electromagnetic spectrum, resulting in an immediate retraction of existing collagen and the subsequent activation of fibroblasts causing non-ablative neocollagenesis. The female urethra is known for having a maximum length of five centimeters, and its anatomical structure and length justifies the use of radiofrequency on the external urethral meatus. Radiofrequency waves can reach a sufficient depth to induce collagen production in the whole urethra. RF has shown to be a treatment with low adverse effect. Patients reported no symptoms during or after treatment [29, 30] (Lordelo et Al 2017, Sodré et Al 2019). In **Figure 9**, the intracavitary electrodes are shown. E electrode (a) is the general one, to work vaginal and anal. The (b) is specific for pediatrics and vaginismus, because it is thinner for applications in which the (a) and it will be more difficult to apply. The (c) is rectal for anal application only. And the d is for specific rectal application, in specific and focused points. With this, the entire pelvic floor can be addressed intracavitary. These devices apply energy to the vagina in 360°.

The capacitive intracavitary device, shaped like a finger, allows not only the penetration of the energy that passes through the (**Figure 10**) pelvic floor structure

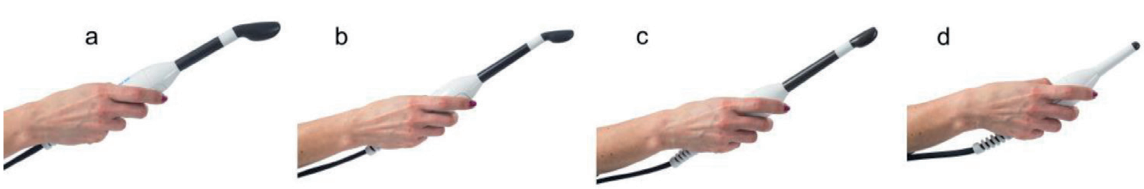

Figure 9.
Different capacitive intracacavitary vaginal devices.

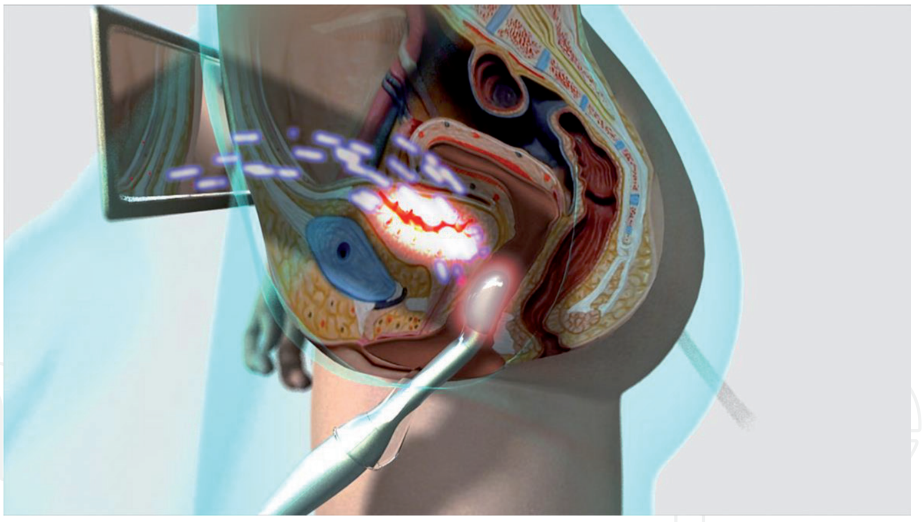

Figure 10.
Diagram of the use of the intracavitary device. The movement of energy towards the passive plate can be observed.

but also massages the vaginal region, allowing the vaginal introitus to reach the entire length of the vagina, which makes the urethra receive the necessary energy, to produce structural changes, to improve urinary incontinence.

11. The state of the technology

The state of the art determines the technological evolution of the equipment. Within the market, there are models with different characteristics and benefits, which present significant differences in energy delivery and, consequently, in obtaining results. It is important to become familiar with the available device options to gauge expectations for therapeutic efficacy.

The first generation of equipment was developed in the 80s. Today, they are still in the market with an exclusively manual use feature. They have a single channel, with a capacitive electrode holder, a resistive electrode holder and a return plate. The power of this equipment varies between 50 and 250 W.

The second generation of equipment was developed in the 2010s. This new technological family was characterized by increasing performance, as well as power, since the supply of electronic components allowed more complicated designs. The equipment of this second generation has an automatic working option, in addition to the classic capacitive and resistive electrode holders; they allow working in multi-channel (that is, several channels within the same container), they have a temperature sensor and even allow an intracavitary approach with controlled temperature. The input powers of these devices start at 300 W.

Although it is true that all devices start from the same type of energy, the dosage provided by both technologies makes a difference at the therapeutic level. This factor determines, not only a physiological improvement in obtaining results of 75%, but even that some equipment with temperature sensors avoid the absolute contraindication of its application in sensitivity disorders, when the temperature of the device can be controlled.

12. Cautions and contraindications with the use of radiofrequency

Over the years, a large number of contraindications to radiofrequency therapy have been identified. Some are clearly documented, others are based on assumptions. Others still depend on the dose or the location. For these reasons, the contraindications are divided into:

12.1 Absolute contraindications

Pregnancy - In view of the rapid division of embryonic tissue and the blood supply to the placenta, it is not advisable to treat pregnant women with radiofrequency.

Active bacterial infectious diseases (e.g. Tuberculosis) - In certain forms of tuberculosis or in active infections, heating in deep tissue can cause a large decrease in the number of leukocytes. Viral infections, on the contrary, have shown a positive reaction to the therapy.

Implanted electronic device - it is recommended that a patient with an implanted electronic device (e.g. cardiac pacemaker) not be subjected to radiofrequency, unless a specialized medical opinion has been previously obtained.

Hearing aids - Hearing aids must be removed. If they are subjected to radio frequency, hearing aids may experience irregularities in their operation. People with pacemakers and hearing aids should therefore not remain in the vicinity of radio frequency equipment when they are switched on.

Fever - Using radio frequency with fever can further increase metabolism. This could cause an even higher rise in temperature, leading to hyperthermia.

Neoformations - Active cancer is a contraindication when blood flow may imply the dissemination of the metastasis. Treatment of some muscular skeleton diseases may be accepted even when the patient has cancer, when this specification is detailed in the diathermy device User's Manual.

Sensitivity alterations - The application of radiofrequency should be used with caution on areas with sensory alterations. Special care is needed also for debilitated patients, since dosimetry depends largely on the sensation of heat felt by the patient. Pain is an indication that excessive heat is occurring. Sensitivity alteration is an absolute contraindication in devices with no temperature sensor control. This contraindication is avoided when the device has temperature sensor control and can be adjusted to a tolerable temperature without risk of burns.

12.2 Relative contraindications

Rheumatoid arthritis - Researchers report that deep heating in the treated joints can increase enzyme activity and induce breakdown of articular cartilage. Nevertheless, diathermy treatment in athermal or moderately thermal mode has shown a positive reaction. Dose management is important, and should be precise.

Large metal implants - Metals concentrate electromagnetic energy. To prevent possible concentrations of energy, around the implant and the resulting dangers (burns), radio frequency application should only be used if the indications are more important than the possible adverse effects while using specific guidelines and applied in mobile modalities with dose management.

Chronic systemic diseases - In decompensated chronic diseases such as diabetes, hypertension, coronary artery disease, kidney failure, etc. the use of radiofrequency concomitant to decompensated systemic diseases can induce adverse effects.

13. Conclusions

This chapter discusses the main effects of high-power, multi-channel radio frequency in sports lessons, the most important factor determining whether a diathermy device increases intracellular signaling, vascularity, and body temperature is the amount of energy absorbed by the tissue. This energy is provided in Tecartherapy devices through the generation of an electromagnetic field, and through the use of capacitive and resistive electrodes. The key results that contribute to improving sports injuries are presented, being able to improve, including muscular capacities. This electromagnetic field will have various metabolic effects on the vascular, musculoskeletal and immune systems, which are beneficial for work in different areas of health such as sports, pain, the vascular area, urogynecology, important in urinary incontinence in athletes, feminine among others, being increasingly extensible to other fields of health. This procedure is safe, with no known side effects, and the patient can be returned to normal activity immediately.

Manufactured Device.

Pictures courtesy of Capenergy Medical, S.L. Barcelona, Spain.

Author details

Jesús Clemente Rodríguez Lastra[1*] and Ester Piñero Mendez[2]

1 Universidad Carabobo, Valencia, Venezuela

2 INNEO Clinic, Barcelona, Spain

*Address all correspondence to: jjrrll51@gmail.com

References

[1] Culotta, Ch. A. (1970). «Arsonval, Arsène D'». Diccionario de Biografía Científica 1. New York: Charles Scribner's Sons. pp. 302-305

[2] Ivorra A Bioimpedance monitoring for physicians: an overview 2002 Medicine for non-physicians, Hospital Clínic de Barcelona. https://intellbio.com/wp-content/uploads/2019/09/bio-impedance-monitoring-for-physicians-1.pdf.

[3] Ling S J, Moebs W, Sanny J. Cap. 109. Energy Carried by Electromagnetic Waves 2019 University Physics Volume 2 https://opentextbc.ca/universityphysicsv2openstax/

[4] Romanenko, S., Begley, R., Harvey, A. R., Hool, L., & Wallace, V. P. (2017). The interaction between electromagnetic fields at megahertz, gigahertz and terahertz frequencies with cells, tissues and organisms: risks and potential. Journal of the Royal Society, Interface, 14(137), 20170585. https://doi.org/10.1098/rsif.2017.0585.

[5] Perez CA, Scott C, Emami B, et al. Evaluation of 45 degrees C hyperthermia and irradiation. II. A phase I clinical trial in humans by the Radiation Therapy Oncology Group. Am J Clin Oncol 1993;16:477-481.

[6] Wooda, A. Karipidisb K Radio-frequency Fields and Calcium Movements Into and Out of Cells. Radiation Research. 2021 195, 101-113.

[7] Pall L M. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. J Cell Mol Med. 2013 Aug; 17(8): 958-965.

[8] Aaron RK, Boyan BD, Ciombor DM, Schwartz Z, Simon BJ. Stimulation of growth factor synthesis by electric and electromagnetic fields. Clin Orthop Relat Res. 2004 Feb;(419):30-37.

[9] De Mattei M, Fini M, Setti S, Ongaro A, Gemmati D, et al. Proteoglycan synthesis in bovine articular cartilage explants exposed to different low-frequency low-energy pulsed electromagnetic fields. Osteoarthritis Cartilage. 2007; 15: 163-168.

[10] De Mattei M, Caruso A, Traina GC, Pezzetti F, Baroni T, et al. Correlation between pulsed electromagnetic fields exposure time and cell proliferation increase in human osteosarcoma cell lines and human normal osteoblast cells in vitro. Bioelectromagnetics. 1999; 20: 177-182.

[11] Lohmann CH, Schwartz Z, Liu Y, Guerkov H, Dean DD, et al. Pulsed electromagnetic field stimulation of MG63 osteoblast-like cells affects differentiation and local factor production. J Orthop Res. 2000; 18: 637-646.

[12] Heermeier K, Spanner M, Trager J, Gradinger R, Strauss PG, et al. Effects of extremely low frequency electromagnetic field (EMF) on collagen type I mRNA expression and extracellular matrix synthesis of human osteoblastic cells. Bioelectromagnetics. 1998; 19: 222-231.

[13] Hartig M, Joos U, Wiesmann HP. Capacitively coupled electric fields accelerate proliferation of osteoblast-like primary cells and increase bone extracellular matrix formation in vitro. Eur Biophys J. 2000; 29: 499-506.

[14] Thamsborg G, Florescu A, Oturai P, Fallentin E, Tritsaris K, et al. Treatment of knee osteoarthritiswith pulsed electromagnetic fields: a randomized,double-blind, placebo-controlled study. Osteoarthritis Cartilage. 2005; 13: 575-581.

[15] Goldring MB. The role of the chondrocyte in osteoarthritis. Arthritis Rheum. 2000; 43: 1916-1926

[16] Cau N, Cimolin V, Aspesi V, Galli M, Postiglione F, Todisco A, Tacchini E, Darno D, Capodaglio P. Preliminary evidence of effectiveness of TECAR in lymphedema. Lymphology. 2019;52(1): 35-43.

[17] Duñabeitia I, Arrieta H, Torres-Unda J, Gil J, Santos-Concejero J, Gil SM, Irazusta J, Bidaurrazaga-Letona I. Effects of a capacitive-resistive electric transfer therapy on physiological and biomechanical parameters in recreational runners: A randomized controlled crossover trial. Phys Ther Sport. 2018 Jul;32:227-234.

[18] Rea, W. Kapur S, Mutagi H. Radiofrequency therapies in chronic pain, Continuing Education in Anaesthesia Critical Care & Pain, 2011; 11; 2, 2011, 35-38. https://doi.org/10.1093/bjaceaccp/mkq057.

[19] Bretelle F, Fabre C, Golka M, Pauly V, Roth B, Bechadergue V, et al. (2020) Capacitiveresistive radiofrequency therapy to treat postpartum perineal pain: A randomized study. PLoS ONE 15(4): e0231869. https://doi.org/10.1371/journal.pone.0231869.

[20] Tramuntana A. Comparative Study of the Use of the Latest Generation Therapy, with previous equipment and using Lymphatic Drainage in Pain. Personal Communication 2020.

[21] Pilla A, Fitzsimmons R, Muehsam D, Wu J, Rohde C, Casper D. Electromagnetic fields as first messenger in biological signaling: Application to calmodulin-dependent signaling in tissue repair. Biochim Biophys Acta. 2011 Dec;1810(12):1236-1245. doi: 10.1016/j.bbagen.2011.10.001.

[22] Melzack R, Stillwell DM, Fox EJ. Trigger points and acupuncture points for pain: correlations and implications. Pain. 1977;3:3-23.

[23] Akamatsu FE, Ayres BR, Saleh SO, et al. Trigger points: an anatomical substratum. BioMed Res Int. 2015: 623287.

[24] Blank M. Do electromagnetic fields interact with electrons in the Na,K-ATPase? Bioelectromagnetics. 2005 Dec;26(8):677-683. doi: 10.1002/bem.20167. PMID: 16189824.

[25] Hazlewood C.F, Markov M.S. Could the relief of myofascial and/or low back pain by magnetic fields be explained by their action on trigger points. Environmentalist (2007) 27:447-451.

[26] Karpati G, Carpenter S: Micropuncture lesions of skeletal muscle cells: A new experimental model for the study of muscle cell damage, repair, and regeneration. In Schotland DL (ed): Disorders of the Motor Unit. New York, NY, John Wiley & Sons Inc, 1982, pp. 517-533.

[27] Ryland B. Edwards, Mark D. Markel, Radiofrequency energy treatment effects on articular cartilage, Operative Techniques in Orthopaedics, 2001; 11, 2, 2001, 96-104.

[28] Thyssen, H. H., Clevin, L., Olesen, S., & Lose, G. (2002). Urinary Incontinence in Elite Female Athletes and Dancers. International Urogynecology Journal, 13(1), 15-17.

[29] Lordelo, P., Vilas Boas, A., Sodré, D., Lemos, A., Tozetto, S., & Brasil, C. (2017). New concept for treating female stress urinary incontinence with radiofrequency. International braz j urol : official journal of the Brazilian Society of Urology, 43(5), 896-902.

[30] Sodré DSM, Sodré PRS, Brasil C, Teles A, Dória M, Café LE, Lordelo P. New concept for treating urinary incontinence after radical prostatectomy with radiofrequency: phase 1 clinical trial. Lasers Med Sci. 2019 Dec;34(9):1865-1871.