Litwa Ewelina, Dobosiewicz Anna Maria, Miętkowska Paulina, Różański Gracjan, Badiuk Nataliia. The rehabilitation in carpal tunnel syndrome. Journal of Education, Health and Sport. 2018;8(11):976-989. eISNN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.3017152
http://ojs.ukw.edu.pl/index.php/johs/article/view/6899

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part b item 1223 (26/01/2017).
1223 Journal of Education, Health and Sport eISSN 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 19.12.2018. Revised: 22.12.2018. Accepted: 24.12.2018.

The rehabilitation in carpal tunnel syndrome

Ewelina Litwa[1], Anna Maria Dobosiewicz[1],Paulina Miętkowska, Gracjan Różański[1], Nataliia Badiuk[2]

[1]Scientific Circle at Department of Hygiene, Epidemiology and Ergonomics. Division of Ergonomics and Exercise Physiology, Nicolaus Copernicus University in Toruń, Collegium Medicum in Bydgoszcz, Poland
[2]State Enterprise Ukrainian Research Institute for Medicine of Transport, Ministry of Health of Ukraine, Odesa, Ukraine

Corresponding author: Anna Maria Dobosiewicz, annamdobo@gmail.com

Abstract

Carpal tunnel syndrome is a neuropathy of the upper limb. It occurs in the wrist. To present the different physiotherapeutic methods for the treatment of carpal tunnel syndrome. Physiotherapeutic methods can be divided into methods of kinesitherapy and physiotherapy. Techniques include kinesiotherapeutic neuromobilization, taping rehabilitation. While the physiotherapy: sonotherapy, laser and transcutaneous electrical nerve stimulation. The effectiveness of these treatments in the carpal tunnel syndrome has been supported by research.

Keywords: Carpal tunnel syndrome; physiotherapy; neuromobilization; conservative methods; physical therapy

Introduction

Carpal tunnel syndrome (CTS) is one of the most common neuropathy upper limb. It occurs in the wrist. Following the increase in pressure within the carpal tunnel comes to compressing the median nerve, which in turn leads to the appearance of symptoms characteristic of the condition. Symptoms of carpal tunnel syndrome are pain, numbness and paresthesias in the area of the hand and wrist. A common symptom for this team are nocturnal pain that awaken patients from sleep. During the advancement of the disease appears thenar muscle atrophy, impaired sense of touch and temperature sensation disorders, and efficiency of his hand.

Carpal tunnel syndrome is one of the some of the illnesses associated with the overload musculoskeletal. Occupational risk factors that lead to this condition are: repeatability of hand movements, the use of excessive force, vibration, still perform the same movements and uncomfortable position, which is charged wrist joint. In addition to the above factors, which lead to carpal tunnel syndrome distinguished, inter alia, having traumatic, vascular, rheumatic diseases, hormonal changes, but also to obesity.

The aim of the article is to present physiotherapy techniques, which are used in the treatment of carpal tunnel syndrome. Among them stands out neuromobilization, taping rehabilitation, sonotherapy, laser and transcutaneous electrical stimulation.

Neuromobilization median nerve

Neuromobilization belongs to manual therapy techniques. This method deals with the development of the nervous tissue itself, but also the tissue surrounding the nervous system. This allows the renewal of the strength of the system, ie., the restored is the ability to move the elements relative to each other, which surround the arrangement. Furthermore neuromobilization restores the ability of the nerve tissue, and for tensioning to correct and renew the physiology of nerve cells [1].

Neuromobilization should be introduced in the initial phase of the disease when there is not yet lasting morphological and should apply to all abnormal tissue. This method should include nerve trunk. The purpose of this technique is to improve neuromechanics of the roots of the spinal nerves and the spinal tire and perineural connective tissue by action on the peripheral nerves. Invalid neuromechanics leads to the loss of adaptation of the nervous system to the mechanical load and the movement of which are linked tissue injury of the nervous system and the nervous tissue. The efficiency of this method depends on the correct selection of the pathogenesis and diagnosis techniques appropriate to the current clinical status [1].

In a clinical trial, which is conducted is for the purpose of this technique are used [1]:

- sensory examination of superficial and deep sensation (proprioception)
- study muscle function indicator,
- study muscle response,
- examination by palpation of nerve trunks (teasing)
- study nerve trunks- test voltage and mobility tests.

However, the main study prior to the introduction of appropriate techniques of neuromobilization is testing voltage and mobility of the nerve trunk [1].

Symptoms of these tests are positive [1]:

- provoke pain response, which is characteristic of the disease,
- disproportion in symptoms in a test performed on the opposite limb,
- provoked symptoms must be confirmed by a test to distinguish,
- provoked symptoms must be confirmed by palpation.

The test voltage is a study that tightens the tire core, core and nerve.

Voltage above structures occurs by arranging the joints in the area where these elements extend. Setting joint must be appropriate to adapt the single biggest nervous system. In addition to the arrangement of the joints nervous tension intensity can also be obtained by traction pond. Positive result will indicate the absence of the elastic conductive section [1].

This test is movable, which produces displacement of the nervous system. It comes to the displacement of the test piece by arranging the set of neural tissue at rest. The tension of the nerve distal or proximal to the injury of the nervous system causes a displacement of a tissue perineural. A positive result will indicate the emergence of external factors compression or limitations for the nerve tissue backing [1].

Before the introduction of the neuromobilization treatment it must be eliminated contraindications to the use of this method [1]:

- acute damage to the peripheral and central nervous system,
- tumors of the nervous system and spine
- fever,
- infections and acute inflammation,
- unstable neurological symptoms,
- rest pain,
- evidence of damaged cauda equina,
- instability of the spine - bone or ligamentous,

- congenital anomalies of the spine and peripheral joints,
- lack of cooperation with the patient.

CTS occurs in the area and the wrist is the most common upper extremity neuropathy. As a result of the increase in pressure in the carpal tunnel comes to compressing the median nerve and the appearance of symptoms and to bring neuromobilization median nerve must be placed in correct positions of the upper limb joints, that is, [1]:

- neck bent to the opposite side in relation to the upper limb on which the road is performed,
- shoulder depression (low)
- dissuaded arm in the shoulder joint,
- hyperextended arm horizontal,
- external rotation of the arm,
- elbow erect,
- supination of the forearm,
- snap of the wrist joint,
- snap all phalanges.

The above items positional upper extremity to perform neuromobilization can be changed by the magnification or reduction of the angular orientation of the joints, connecting joints traction, movement in the joints in the right direction, with the right force and the scope of the stacking order, and different joints. And adjusting the switching process is determined by referring to the symptoms observed in the clinical trial [1].

Neuromobilization may not cause pain. Performing techniques of this method should be selected individually for each patient. When performing neuromobilization observe the reactions. With the advent of reaction adjusts the frequency, duration and number of pulses. In the first stage of treatment used two sets of frequencies from two to four per second for a few seconds after pulsed. When it comes to improving the condition of the patient treatment time is increased to twenty - thirty seconds. The time of a single movement, the range of motion in the joints and the number of sets is also increas. In the chronic diseases from doing ten to sixty voltage lasting from one to several hundred seconds. You have to remember, that the above-mentioned methods is determined by the principle of painless method and opposite movement Maigne'a. During execution neuromobilization and after finishing the patient may experience pain [1].

Working properly route the median nerve leading to [1]:

- pain relief,
- increasing the range of motion of joints,
- feeling muscle relaxation,
- improve the blood supply,
- reducing swelling of tissue
- improving axonal transport,
- reduction of sympathetic tone.
- restore proper neuromechanics.
- restore proper physiology of nerve cells.

Neuromobilization to be an effective treatment, but if the diagnosis of the patient will be placed correctly and the nature of the changes will be functional. Neuromobilization can be used in case of a positive result test voltage and mobility. This method belongs to a part of the medical therapy and must be combined with other therapies physiotherapy to get the desired effect [1].

Taping rehabilitation

Taping the medical device to the techniques of conservative treatment of carpal tunnel syndrome. This method allows you to get the beneficial effects of a faster time. Taping is a technique, which combined with other methods of conservative treatment. The possibility of sticking tape is determined by the severity of the symptoms of carpal tunnel syndrome. There are two periods of the disease: the period of acute and chronic period, and therefore, there are two ways to affix the tape [2].

A factor, which leads to the median nerve compression, and thus to the symptoms of carpal tunnel syndrome is an increase in pressure in the carpal tunnel. Maximum flexion of the wrist and its snap such that in these positions the pressure in the channel reaches the highest value. While the lowest pressure exists when the wrist is placed in a small flexion of about 5 degrees and ulnar visit. In order to reduce the pressure must be set in a small wrist flexion and this can be achieved through proper sticking tapes. The best technique that will lead to achieve the desired effect will be to use techniques of muscle. The tape-shaped X adhered to the lateral epicondyle of the humerus and is carried to the dorsal side of index finger and little finger [2].

Another reason, which leads to compression of the median nerve is lateral ligament hypertrophy or increase the tension. In the acute phase, or in remission of the disease

symptoms of the transverse stretching the ligaments of the wrist, sticking of the tape leads to the relaxation of the ligaments or reduction of the severity of the symptoms of carpal tunnel syndrome. To came to the above effect should be used method ligament. Stretch the tape to stick 80-100% and downstream of the transverse wrist ligament. In this technique, use two tapes to influence as much as possible on the ligament. The first strip is glued to the area palmar aponeurosis, and the other on the proximal end of the lateral ligaments of the wrist [2].

The period of the disease is affected by the direction of restraint belt, so stand out [2]:

- during acute tape glued to reach the minimum voltage lateral ligaments of the wrist. For best results, the tape should be applied when the lateral ligament of the wrist is in a relaxed position,
- in remission tape glued to reach enlarging the transverse wrist ligament. Tape causing the carpal tunnel opens from the front. For best results, the tape should be applied when the ligament is stretching.

Medical Taping is one of the methods of conservative treatment in patients suffering from carpal tunnel syndrome. To obtain the advantageous effects it is combined with other forms of medical therapy for example with ultrasound pulsed alternating magnetic field of low frequency or mobilizations and the tampering wrist bone structures [2].

Laser therapy

Laser therapy is one method belonging to physical therapy, which uses laser radiation. Biostimulation use of lasers which output the average radiation power (500 mW). Low-power radiation is not associated with the action of heat, and only, impulse. Thanks to such radiation does not lead to an increase in tissue temperature, and can be used in three periods of the disease acute, subacute and chronic [3, 4, 5].

Currently biostimulation laser is used in many fields, eg. in orthopedics, neurology, rheumatology and musculoskeletal diseases. The use of this treatment is indicated for many diseases, among others, to carpal tunnel syndrome. Prior to the introduction of laser biostimulation treatment, it should be excluded contraindications, which obstruct the operation [3].

Contraindications for carrying out these procedures are [3,5]:

- cancer and cancer risks,
- fever,
- infection,
- epilepsy,

- allergic to light,
- light sensitize medication.

Laser radiation has an effect on reducing pain and can contribute to its complete resolution. Several studies have shown that by irradiation of laser, of inflammation, there is an increase lymphatic drainage and acts on the capillaries and blood. Thanks to laser analgesic, the decrease pain also affects the growth of prostaglandins and endorphins and improving the metabolic processes. In addition to laser radiation increases the effectiveness of protein synthesis, improving cell regeneration, improving blood vessel health, nutrition improvement and tissues and improvement of blood flow. Laser therapy also works anti-inflammatory. Furthermore, the effect of laser radiation has an impact on many other processes including an increase in phagocytosis.

The carpal tunnel syndrome with a laser spot using the technique contact, but without the pressure to the structure of the wrist (Fig. 1) .In the acute phase of carpal tunnel syndrome, a dose of 0,1J / cm 2 to 3 J / cm^2, a low frequency. During this period it is recommended to perform in a series of 10 treatments. During the chronic condition of a dose to 6J / cm^2 and slow frequency. During this periodit is recommended to perform in a series of 10 -15 treatments [5].

Fig.1 Point laser therapy on the wrist- *own source* [6].

There are many studies showing the effectiveness of laser treatment in carpal tunnel syndrome.

Evcik [7] in their study assessed the effectiveness of laser treatment of carpal tunnel syndrome. Patients were divided into two groups. The first group was used laser, and in the second group of dummy procedure. After the series of treatments gave the increase of the gripping force and to improve the properties of nerve conduction in the group where the laser is used. In both groups, decrease sham surgery day and night pain, reduce symptoms and increase of nerve conduction.

Shooshtari [8] conducted similar tests as Evcik. He divided the patients into two groups. In the first group they use laser to the area of the wrist on the following parameters: 785 nm and a pulse energy of 9-11 J / cm^2, 400 mW, while the second group used the application sham. In the first group reported pain reduction and increase in strength of hand grip. In addition, the sensory fibers of the median nerve observed improvement in conduction velocity. The improvement was also noticeable in the sensory and motor fibers in terms of latency final. In the second group it was observed only relief of pain and paresthesia. It has been found that the improvement of the clinical symptoms of pain and reduction leads to an increased strength of the hand grip and the laser can be used in patients as a complementary method to treat mild to moderate form of carpal tunnel syndrome.

Ultrasounds

Ultrasounds are among the most commonly used methods of physiotherapy in the treatment of many diseases of the musculoskeletal system. Different tissues have different absorption capabilities of ultrasound. Nerve tissue manifests the greatest sound absorption. Less sound absorption of the nerve tissue revealed muscle tissue, and adipose tissue shows the least. Therefore, the right-Grotthus Draper is that the reaction in the tissues caused by the ultrasonic energy will appear when this energy is absorbed in the appropriate amount of tissue [3, 9, 10].

Ultrasound among the thermotherapy because the process of absorption of ultrasonic energy by the tissue through which involves the process of conversion of mechanical vibrations into heat. In addition to the action of heat, ultrasound, exhibit mechanical and physicochemical properties. Operation of physicochemical affect the physical and chemical properties of the tissue. Among other things, lead to the conversion of ultrasound proteins from gel state to sol state, and to oxidation chemical reactions. Mechanical action often referred to as micro-massage which is caused by the variation of pressure in the direction of propagation of the ultrasonic wave [3, 9].

These activities belong to the local changes, that is the original. These are changes in the tissue, existing at the time and in the place of sonication. In addition to changes in the local stands out also changes general, that is secondary. These changes pole the whole body. The main effects of ultrasound should be [3, 4, 9]:

- analgesic effect,
- reduction of muscle tension,
- increase in tissue regeneration,
- slowing inflammatory processes
- increase extensibility of collagen fibers.

Before the implementation of ultrasound for treatment, contraindications should be eliminated to prevent the carrying out surgery. These include [3, 4]:

- advanced atherosclerotic changes in vessels,
- pacemaker,
- metallic foreign bodies present in the tissues.
- neuralgia of unknown origin,
- area of the spine above C3.

Ultrasound is often used in the treatment of carpal tunnel syndrome. In the early period of the intermediate and neuropathy, are part of the ultrasound treatment of the median nerve conduction, but also connective structures. Due to the position of the median nerve uses the ultrasound pulse. The fill factor of the period should be 25% and the energy intensity approx 1 W / cm^2, and thus the average intensity time should be 0.25 W / cm^2. For sonication median nerve head used in an area of 1cm^2 and frequency 3MHz wave (Fig. 2) [11].

Fig. 2 Ultrasounds therapy on the wrist- *own source* [6].

Many studies support the use of ultrasonic waves to treat carpal tunnel syndrome.

Dakowicz and Latosiewicz [12] investigated the efficacy of physiotherapy treatments, including ultrasound to carpal tunnel syndrome. They divided the patients into two groups according to Whitley. In the first group were people with early disease, with small, periodically occurring ailments, which occurred at night and woke patients from sleep. While the second group included patients with the intermediate form of neuropathy, with symptoms occurring constantly. Both groups were two types of treatments for the wrist area. The first type was the iontophoresis treatment, while the second sonoterapia at a dose 0,5-0,8W / cm^2, 48Hz, 1 MHz with a 25% duty cycle. The duration of treatment was 3-6 minutes. It was a series of 10 treatments, performed once a day. It was found statistically significant reduction of pain in the daytime and nighttime, reducing discomfort and improving hand function in a self-service in both the first and second. With iontophoresis it occurred and ultrasonicated to accelerate absorption swelling of the tissues that surround the median nerve, which led to the improvement of nerve conduction.

Bakhtiary et al. [13] in their study of patients randomly divided into two groups. They divided patients with confirmed carpal tunnel syndrome into two groups. The first group uses ultrasound to the right and laser therapy for the left hand, while the second group of ultrasound used for the left hand, while the laser to the right. There has been the effectiveness of ultrasound in all the examined parameters (pain, grip strength, and in the study of nerve conduction). Studies have shown that ultrasound also affected the latency sensory and motor, and the amplitude have little impact.

On the other hand Kwolek and Zwolińska [10] in their study divided patients with carpal tunnel syndrome in three groups. In each of the three groups used massage whirlpool, automobilization brachial plexus and the median nerve and sonotherapy. In each of the groups using another type of ultrasonic wave. The first group was applied: a continuous wave of 0.3 W / cm^2, 8 minutes; Second: the continuous wave of 0.6 W / cm^2, 4 minutes, while in the third: a pulse wave of 0.6 W / cm^2, 8 min, 20% fill factor. For a group of first and second total energy was 720J, and for the third group 288 J. The results shows to reduce pain, to improve the level of self-service, to improve the results of challenge tests mainly test Luthy'ego, Tinnela and grip fatal and there was an increase muscle strength and improve the range of motion. The obtained results show the effectiveness of applied therapy. However, when comparing these groups received better results, this group, which had applied pulsed ultrasound. The researchers concluded that the carpal tunnel syndrome and medium dose weak ultrasonic wave leads to a reduction of clinical symptoms and have found that the

results obtained for the therapeutic program determines the total amount of energy that is transferred to the tissues.

Transcutaneous electrical stimulation (TENS)

Electrotherapy is also a method belonging to physical therapy. In electrotherapy is used direct current and alternating. In the treatment of pain often used in transcutaneous electrical nerve stimulation (TENS). These alternating currents are pulsed with a rectangular, triangular or sinusoidal pulse. TENS is a technique used to treat both acute and chronic pain [15, 16].

Most TENS uses high frequency, which is referred to as a conventional TENS. Aβ fibers, which are responsible for conduction sense of touch are stimulated by this type of TENS. Melzack and Wall in 1965 [14] reported theory controlled passage of the core, which states that "the fibers Aβ activate GABAergic interneurons substance gelatinous Roland in the corners of the spinal cord, and in turn, cause a presynaptic block in the central ends of the fiber Aδ and C (conductive feeling pain from peripheral tissues to the posterior horn of the spinal cord). The consequence of this action is the inhibition of the pain impulse to the higher floors of the central nervous system (CNS). "This stimulation stimulates activity at the spinal cord level and activating the process analgesic subbrachialis centers.

Electrical stimulation leads to an increase in the local flow, which helps in the healing process. As a result, this leads to increased levels of carbon dioxide, increased oxygen consumption and to increase lactic acid and other metabolic products. In addition to this it comes to expedite the transport of nutrients and a localized increase of circulation and the temperature [17].

Transcutaneous electrical stimulation is used, inter alia, [4, 17]:

- symptoms of post-operative pain,
- post-traumatic,
- rheumatic diseases, orthopedic,
- inflammation of nerves,
- inflammation of the intercostal muscles,
- neuralgia intercostal muscles,
- mononeuropathy eg. in carpal tunnel syndrome.

Contraindications to the method of transcutaneous electrical stimulation are [4.16]:

- patients with pacemakers,

- elevated body temperature.
- skin changes in the planned application of the electrodes,
- pain of unknown etiology.

In carpal tunnel syndrome physiotherapy is an important part of rehabilitation. Treatment, which is quite often used in patients with this kind of neuropathy is TENS, which analgesic effect [17].

Median nerve comprises a motor and sensory fibers, which belongs to the mixed nerves from combinations of spinal nerves at the level of the fifth and sixth cervical vertebra. It can thus be a transcutaneous electrical stimulation of the carpal tunnel syndrome for use sympathetic trunk and nerve root at the C5-C6. With this analgesic effect can be obtained, and adjusting the tension of the sympathetic part of the autonomic nervous system [11].

In TENS electrode is used having a diameter of 3 cm, which are laid longitudinally along the median nerve in the wrist. (Fig. 3) To stimulate the area of the wrist joint radially used parameters such as frequency of 150 Hz, pulse duration of 200 ms and the flow adjusted to the patient's feelings. The patient should feel a vibration or tingling sensation under the electrodes [11].

Fig. 3 TENS along the median nerve in the wist- *own source* [6].

The use of transcutaneous electrical stimulation in the treatment of carpal tunnel syndrome as compared to the above methods is the least frequently used method in the

research. Therefore, there are few available sources describing the effectiveness of this method.

Ciechanowska et al. [17] qualified twenty patients with carpal tunnel syndrome and applied TENS parameters such as time of 50μs pulse, frequency 150 Hz, and the treatment time was 15 min. The electrodes are arranged longitudinally along the extension of the median nerve in the region of the wrist joint radially. The authors conducted research to assess the effectiveness of TENS pain, feeling and grip strength. Studies have shown that after a series of treatments in the study reported an increase in grip strength and reduce pain. In addition, there has been a reduction in the intensity and frequency of pain, improvement of upper limb function, reduced taking painkillers and improve superficial sensation in the area supplied by the median nerve. By reducing the excitability of pain fibers.

SUMMARY:

Carpal tunnel syndrome is one of the diseases, in which there is an overload musculo - skeletal disorders. There is no single effective treatment of this disease. You can use a lot of conservative methods, which may delay the development of disease. Numerous scientific studies indicate that physiotherapy activities described in this article, can significantly improve the quality of life of patients with carpal tunnel syndrome.

REFERENCES

1. Dwornik M, Białoszewski D, Korabiewska I, Wroński Z. Zasady stosowania neuromobilizacji w schorzeniach narządu ruchu . Ortopedia Traumatologia Rehabilitacyjna 2007; 9 (2): 111-121.

2. Georgiew F, Maciejczak A, Otfinowska E. Wykorzystanie tapingu medycznego w leczeniu pacjentów z zespołem kanału nadgarstka. Rehabilitacja Medyczna 2010; (3): 19-23.

3. Mika T, Kasprzak W. Fizykoterapia. Wyd. IV PZWL, Warszawa 2006: 143-145,227-228,357-360,362-364,374.

4. Straburzyński G, Straburzyńska-Lupa A. Medycyna Fizykalna. Wyd. II PZWL, Warszawa 2000: 279-280,284, 338,341-346,405, 407-409,417-418.

5. Biedal M, Janota B, Lisiecki G, Wrodarczyk M, Opara J, Kapko W. Praktyczne zastosowanie lasera niskoenergetycznego w wybranych dysfunkcjach narządu ruchu. Rehabilitacja w praktyce 2012; (6): 48-53.

6. Figure 1-3 - Own source

7. Evcik D, Kavuncu V, Cakir T, Subasi V, Yaman M. Laser therapy in the treatment of carpal tunnel syndrome: a randomized controlled trial. Photomedicine and Laser Surgery2007; 25(1): 34-39.

8. Shooshtari SM, Badiee V, Taghizadeh SH, Nematollahi AH, Amanollahi AH, Grami MT. The effects of low level laser in clinical outcome and neurophysiological results of carpal tunnel syndrome. Electroencephalography and Clinical Neurophysiology2008; 48(5): 229-231.

9. Łukowicz M, Pawlak A, Pawlikowski J, Szymańska J, Dzierżanowski M. Zastosowanie fonoforezy z heparyną w postaci żelu w leczeniu chorób narządu ruchu i urazów sportowych- doniesienie wstępne. Medical and Biological Sciences 2009; 23 (1): 81-86

10. Kwolek A, Zwolińska J. Skuteczność wybranych parametrów fali ultradźwiękowej
w leczeniu zachowawczym zespołu cieśni nadgarstka. Przegląd Medyczny Uniwersytetu Rzeszowskiego 2009; 7 (3): 260-268.

11. Piecha M, Chmielewska D. Fizjoterapia w leczeniu zespołu kanału nadgarstka. Twój przegląd stomatologiczny. 2013; (11): 76-80.

12. Dakowicz A, Kuryliszyn – Moskal A, Latosiewcz R, Kita J, Pogorzelski R. Ocena skuteczności dwóch różnych procedur terapeutycznych w leczeniu zachowawczym zespołu cieśni nadgarstka. Reumatologia 2010; 48 (4): 225-229.

13. Bakhtiary AH, Rashidy-Pour A. Ultrasound and laser therapy in the treatment of carpal tunnel syndrome. Australian Journal of Physiotherapy 2004; 50(3): 147-151.

14. Baysal O, Altay Z, Ozcan C, Ertem K, Yologlu S, Kayhan A. Comparison of three conservative treatment protocols in carpal tunnel syndrome. International Journal of Clinical Practice 2006; 60(7): 820-828.

15. Pyszora A , Kujawa J. Zastosowanie elektroterapii w leczeniu bólu. Polska Medycyna Paliatywna 2003, 2 (3): 167-173.

16. Bańburski S, Pyszora A, Krajnik M, Budzyński J. Działanie przeciwbólowe przezskórnej elektrycznej stymulacji nerwów o wysokiej częstotliwości (H-F TENS). Badanie pilotażowe chorych z przewlekłymi zespołami bólowymi narządu ruchu. Polska Medycyna Paliatywna 2006; 5(3): 120-125.

17. Ciechanowska K, Łukowicz M, Skopowska A, Smuczyński W, Szymańska J. Wpływ terapii TENS na objawy zespołu cieśni kanału nadgarstka. Rehabilitacja w praktyce 2015; (4): 38- 42.