Review Article

Effect of High-Tone External Muscle Stimulation (High-Tone Therapy) in Neuro-Musculoskeletal Disorders: A Narrative Review

Hasan Namvar[1*], Gholamreza Olyaie[1], Hossein Bagheri[1], Ehsan Naiemi[1], Mohammad Hoseinifar[2], Maryam Sargolzehi[2]

1. Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran.
2. Department of Physiotherapy, School of Rehabilitation Sciences, Zahedan University of Medical Sciences, Zahedan, Iran.

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ABSTRACT

High-tone external muscle stimulation (HTEMS) or high-tone therapy is a new type of electrotherapy. Unlike the conventional electrotherapy that uses a fixed frequency, in HTEMS, the frequency and amplitude are simultaneously modulated, delivering much higher energy into the tissues. Recently, considerable attention has been paid to applying high-tone therapy in managing different disorders. This systematic study, therefore, was set out to assess the effect of high-tone therapy in various neuro-musculoskeletal disorders. After an exclusive search in databases of PubMed, Scopus, and Google Scholar, seven relevant studies were selected, including 3 studies for low back pain, 2 studies for peripheral neuropathy, 1 study in multiple sclerosis patients, and 1 preprint study on the subjects with anterior cruciate ligament reconstruction. PEDro (the physiotherapy evidence database) scale was used to assess the quality of the included articles. Although the studies reported that high-tone therapy significantly improved signs and symptoms, the low number and poor methodological quality of included studies do not allow determining certain effectiveness of HTEMS, and it could be an important reason for performing more research in the future.

1. Introduction

Electrical stimulation (ES) is one of the most common conservative treatments that is widely used to reduce pain intensity, improve muscle strength, and muscle re-education in rehabilitation protocols [1, 2]. As mentioned in the previous studies, a multidisciplinary approach is usually used to manage musculoskeletal injuries and disorders, and ES plays an essential role in this approach [3, 4]. It includes various stimulation forms that are classified based on different parameters such as frequency, the direction of the current, and voltage intensity. Regarding frequency, ES is classified

*** Corresponding Author:**
Hasan Namvar, PhD.
Address: *Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran.*
Tel: *+98 (915) 3411746*
E-mail: *Hassan_753@yahoo.com*

into three categories: low-frequency currents (<1000 Hz), medium-frequency currents (1000 to 100000 Hz), and high-frequency currents (>1000000 Hz) [5]. Different types of Transcutaneous electrical nerve stimulation (TENS) and functional electrical stimulation (FES) are two types of low-frequency currents. The mechanism of TENS is based on the gate control theory [3, 6]. Stimulation of primary sensory afferents activates an inhibitory interneuron in the dorsal horn of the spinal cord to inhibit nociceptive signals from small-diameter sensory fibers. While using FES, muscles are stimulated and contracted, and their performance and strength improve [7].

Interferential and Russian currents are two types of medium frequency currents. Interferential current with amplitude modulated at low frequencies is one of the applications of medium-frequency currents. The advantages of interferential current are impedance reduction of skin and producing an amplitude-modulated frequency parameter within the soft tissue [8]. Interferential current increases circulation, reduces pain, and stimulates muscles to contract [8]. Russian current is a type of alternating current at a frequency of 2.5 kHz typically applied in sinusoidal bursts of 50 Hz and a duty cycle of 50% [5]. Previous studies evaluating Russian currents observed the effects of Russian currents on the improvement of muscle strength [9-11].

Furthermore, high-frequency currents generate deep heat within the treatment area [5]. In recent years, there has been an increasing interest in using high-tone external muscle stimulation (high-tone therapy).

High-tone external muscle stimulation (HTEMS) or high-tone therapy is a new alternative approach to electrotherapy techniques that are used in the management of pain. Several hypotheses have been proposed to explain the effectiveness of high-tone therapy.

The mechanism of HTEMS action may be related to normalizing tissue metabolism. Similar to the conventional ES that stimulates nerves and muscles, tissue metabolism can be affected using high–tone therapy through increased cell energy and fluctuation of the cell membrane potential. Using a broad-spectrum frequency, tissue structures can oscillate, and the tissue metabolism and cell processes can be normalized.

Regarding the multiple parameters of ES, two methods have been frequently used: fixed and variable. In conventional electrotherapy, a fixed frequency is used, and there is no frequency scan while the amplitude can be modulated. In high-tone therapy, frequency and amplitude are simultaneously modulated, and a scanned frequency is applied. HTEMS delivers up to 5.000 mW energy with frequencies between 4.096 Hz and 32.768 Hz into the body. In high-tone therapy, all frequencies are applied one after another. The higher frequencies produce more energy. In a practical view, there are some differences between conventional ES and high-tone therapy. Compared to the conventional ES, the time duration of high-tone therapy can last up to 60 minutes, and more than 4 channels can be simultaneously used. There are two current types of HTEMS: HTEMS without muscle and nerve stimulation and HTEMS with muscle and nerve stimulation. In both methods, high-tone therapy affects the metabolic process of tissues. The frequency scan can oscillate tissue structures and move waste products away from the concentration area; it is helpful to reduce pain in inflammation. Another mode of high-tone therapy, besides the metabolic effects, stimulates muscles and peripheral nerves. The tissue stimulation with high-tone therapy is different from the conventional ES methods. This difference can be explained using the existence of frequency modulation of the HTEMS [12-16].

Several attempts have been made to investigate the effects of high-tone therapy in managing various disorders. In this narrative review study, we aimed to review the studies that have assessed the effects of high-tone therapy in improving signs and symptoms of various neuro-musculoskeletal disorders.

2. Materials and Methods

Study design

The purpose of this study was to review the research into the effectiveness of high-tone therapy in treating neuro-musculoskeletal disorders.

Eligibility criteria

In our study, the PICOS (P: Patient/population; I: Intervention; C: Comparison; O: Outcome; S: Study design) framework comprised the following items: P for "subjects with any neuro-musculoskeletal disorder;" I for "high-tone therapy;" C for "sham treatment," "no treatment," "routine treatment," or "standard treatment;" O for "pain," or "function;" and S for "clinical trials "or "randomized controlled trial".

In this narrative review study, we included only trials published in English with full text and assessed the effect of high-tone therapy in neuro-musculoskeletal disorders. We excluded studies that were not published in English and

have not assessed the effectiveness of high-tone therapy in musculoskeletal disorders and neurology diseases.

Sources of research

The search for this narrative review was performed in PubMed database, Medline (PubMed), Scopus database, and Google Scholar. We searched the mentioned electronic databases from 2000 to 2020.

Search strategy

The search keywords and terms were as follows: "high-tone" OR "high-tone external muscle stimulation" OR "high-tone therapy" OR "high-tone stimulation."

Methodological quality

The methodological quality of the included studies was checked using the Physiotherapy Evidence-based Database (PEDro) 11-item scale [17, 18]. Based on the PEDro scale, the articles are categorized into three qualities, high quality (6-10/10), fair quality (4-5/10), and poor quality (≤3/10). PEDro scale is a helpful tool to identify the quality of randomized controlled trial studies and clinical trials. The validity and reliability of this scale have previously been confirmed [19]. Two authors (HN, EN) separately assessed the quality of the included studies.

Results

Literature search and characteristics of the included studies

Our findings showed that high-tone therapy had been mainly used in renal disease, peripheral neuropathy, low back pain, and multiple sclerosis (MS). In total, 228 potentially relevant studies were identified after the origi-

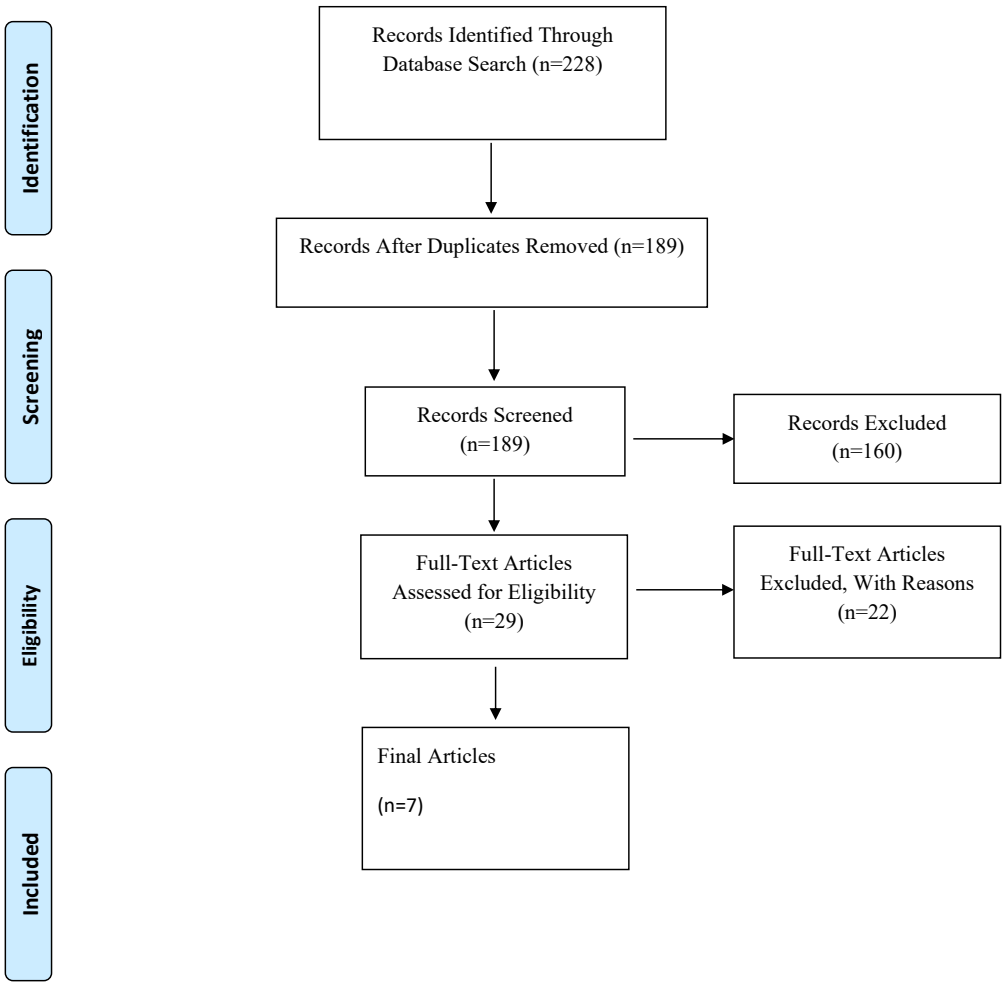

Figure 1. Flowchart of study selection

nal search of the databases. First, the duplicates were removed. Initial screening was performed based on the titles and or abstracts by two reviewers (HN and EN). Then, the full texts were screened by two authors (HN, EN) separately, and 7 studies remained. Figure 1 shows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of the selection strategy of the trials.

Seven studies were finally selected, including three studies for low back pain [14, 15, 20], two studies for peripheral neuropathy [16, 21], one study in MS patients [22], and one preprint study in Anterior Cruciate Ligament (ACL) reconstruction [23].

Description of selected studies

Kerstin Kempf et al. [15] investigated the effects of high-tone therapy compared to TENS in patients with chronic sciatica that had pain duration of more than 3 months. This study was designed as a crossover trial with a wash-out phase of 7 days. In the first phase, the patients were randomly (1.5:1) assigned into two groups. A total of 59 patients received an initial intervention with HTEMS, and then the intervention was replaced after wash-out time with TENS. Also, 41 patients received TENS, and after the wash-out period, it was followed with HTEMS. No information was found about the location of electrode placement. In each phase, the treatment was performed five times per week. Each treatment session lasted almost 45 min. The primary outcome was pain intensity, assessed by the Visual Analog Scale (VAS) and measured at baseline, after the first phase, and at the end of the second phase. Results showed that at the end of the first phase of the study, there was a significant difference between the two treatment groups, and the patients in the HTEMS group experienced more pain reduction. However, after the second phase, there was no significant difference between the two groups. Furthermore, a clinical significance for pain improvement in the HTEMS group was observed. The PEDro scoring of the article was 5/10 (fair quality).

In another study, Darwish Mohamed et al. [14] evaluated the effectiveness of HTEMS versus TENS in radicular leg pain. A total of 100 patients with chronic sciatica participated in this crossover trial. The patients were randomized to be treated by HTEMS or TENS. The treatment was performed four times within 10 days. The wash-out phase was 3 days. The outcome variables were pain intensity, measured with VAS. After the end of the first phase, compared to the baseline, pain intensity was decreased in the HTEMS group, and there was a significant difference between the two groups after the end of the first phase. A comparison of pain intensity revealed significant changes after the second phase in both groups compared to the wash-out phase. The HTEMS group experienced significant pain reduction compared to the TENS group after the second phase. The PEDro scoring of the article was 3/10 (poor quality).

Joanna Szymańska et al. [20] evaluated the effectiveness of high-tone therapy on gait and walking distance in low back pain subjects with claudication. A total of 68 patients were randomly assigned to the HTEMS group and the control group (sham HTEMS group). The outcomes were claudication, evaluation, and measurement of blood flow of lower extremity that was measured at baseline and after the intervention. Compared to the baseline, a significant improvement in claudication and distance walking was observed in the real HTEMS. Also, laser Doppler flowmetry showed an increase in blood flow following high-tone therapy. The PEDro scoring of the article was 3/10 (poor quality).

In a preprint article, Ogrodzka-Ciechanowicz et al. [23] investigated the effects of high-tone therapy on muscle strength recovery in subjects with Anterior Cruciate Ligament (ACL) reconstruction. A total of 35 subjects after ACL reconstruction were randomly divided into two groups. The experimental group received high-tone therapy plus therapeutic exercise, and the control group received only therapeutic exercise. The outcome measures were pain intensity, maximum muscle torque, and knee Range of Motion (ROM). Results showed no significant differences between the two groups in the outcomes. The PEDro scoring of the article was 2/10 (poor quality).

Reichstein et al. evaluated [21] the effectiveness of HTEMS compared to TENS on distal symmetrical sensory polyneuropathy in subjects with type 2 diabetes mellitus. In this study, 41 subjects with type 2 diabetes mellitus were randomized to receive either one of two interventions: HTEMS (20 subjects) or TENS (21 subjects). Both groups received the intervention for 30 min per session for three consecutive days. Outcome measures included pain, numbness, numbness in painful areas, burning, paresthesia, and dysesthesia in the lower extremities. The outcomes were measured at baseline, immediately after treatment, and two days after the intervention. In the HTEMS group, the electrodes were placed on the quadriceps muscle of the lower extremities, and in the TENS group, the electrodes were placed on the legs. About 33% of the TENS group and 80% of the HTEMS group showed an improvement in their symptoms. The painful and non-painful subjects in the

HTEMS group experienced more improvement than the TENS group. In this pilot study, it was concluded that HTEMS could alleviate pain and discomfort-related neuropathy. The PEDro scoring of the article was 4/10 (fair quality).

Kerstin Kempf et al. [16] investigated the effectiveness of HTEMS for four weeks on neuropathic symptoms in subjects with diabetes mellitus. A total of 414 patients with symptomatic diabetic neuropathy were recruited for the study. The outcomes were assessed at baseline, after the first week, after the third week, and finally, three weeks after the end of the intervention. A statistical significance was observed after the intervention period compared to the baseline for all outcomes. Some of the symptoms recurred after the follow-up period. Results of the study showed that HTEMS could be an effective alternative intervention for patients with diabetic neuropathy. The PEDro scoring of the article was 3/10 (poor quality).

In another study [22], 20 MS patients were assigned to the HTEMS group (n=10) and the control group (n=10). The control group received HTEMS for 60 minutes per session over 15 days, and the control group received exercise therapy. The outcomes were disability level measured using an expanded disability status scale and Barthel activity daily living index and quality of life. Results of this study showed that the outcomes improved after the intervention in both groups. This study was in Polish, so the quality assessment of this study was not performed.

4. Discussion

The first objective of this review was to assess the studies that used high-tone therapy in musculoskeletal and neurological disorders. The second objective was to determine the evidence for the usefulness of high-tone therapy in managing signs and symptoms of the mentioned disorders.

Recently, researchers and clinicians have shown an increased interest in using high-tone therapy for various ailments. High-tone therapy is one type of electrical stimulation that, in contrast to traditional stimulation, uses a simultaneous modulation of frequency and amplitude. This mechanism can be a possible reason for the conduction of more energy into the tissue, and it seems possible that due to delivering more energy, tissue metabolism may be affected, and pain and inflammation reduction can occur [13, 15].

Seven articles were assessed for this review [14-16, 20-23]. Three studies were related to low back pain, two studies evaluated the effects of high-tone therapy in diabetic neuropathy, one study was related to MS patients, and one preprint study assessed the effects of high-tone therapy in subjects with ACL reconstruction. Of seven studies, two studies had a fair quality [15, 21], four studies had poor quality [14, 16, 20, 23], and one study had no quality assessment [22]. All studies reported that following high-tone therapy, and there were significant improvements in signs and symptoms. The major limitation of these studies was low methodological quality.

Electrical stimulation, a conservative treatment method, is vital in controlling pain and muscle contraction in rehabilitation and physiotherapy protocols. Although in most clinical guidelines, using a combination of interventions is usually prescribed, new treatment options such as high-tone therapy have always drawn much interest.

This narrative review revealed many unanswered questions about applying high-tone therapy in rehabilitation and physiotherapy. Therefore, future studies with more substantial methodological quality are recommended to compare high-tone external muscle stimulation with traditional electrotherapy and determine the effectiveness of high-tone therapy in various neurological and musculoskeletal conditions.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

Conceptualization and methodology: Hasan Namvar, Gholamreza Olyaie, and Hossein Bagheri; Search strategy: Hasan Namvar, Ehsan Naiemi, Mohammad Hoseinifar, and Maryam Sargolzehi; Initial draft: Hasan Namvar and Ehsan Naiemi; Approval of the final version of the manuscript: all authors.

Conflict of interest

The authors declared no conflict of interest.

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