Research Article

Comparison of Immediate Effect of High-Power Pain Threshold Ultrasound and Deep Transverse Friction Massage on Active Myofascial Trigger Points

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ABSTRACT

Introduction: The study was conducted to compare the immediate effect of high-power pain threshold ultrasound (HPPTUS) and deep transverse friction massage (DTFM) as a traditional technique on the treatment of upper trapezius active myofascial trigger points in male patients with mechanical neck pain.

Materials and Methods: In this parallel single-blind randomized clinical trial study, 60 men with mechanical neck pain (mean age: 30.57±6.19 years) who met the inclusion and exclusion criteria were randomly assigned to HPPTUS and DTFM as the control group. A visual analog scale (VAS), pain pressure threshold (PPT), and range of motion (ROM) of cervical lateral flexion (CLF) were assessed before and after treatment.

Results: Analysis of pre- and post-treatment findings showed that the VAS ($P<0.01$), PPT ($P<0.01$), and ROM of CLF ($P<0.01$) improved significantly in both groups while ROM of CLF increased significantly more in the HPPTUS group. An indirect correlation was found between the pre-treatment ROM of CLF and ROM of CLF improvement in both groups. A significant indirect correlation was observed between pre-treatment VAS and ROM of CLF improvement in the HPPTUS group. In the DTFM group a significant indirect correlation was found between pre-treatment ROM of CLF and VAS improvement.

Conclusion: The results showed that HPPTUS can be used as an effective treatment for active trigger points (TP). It seems that this method is more effective than deep transverse friction massage.

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1. Introduction

Myofascial pain syndrome (MPS) could be the main cause of pain in the neck region and the upper trapezius muscle is one of the most commonly engaged muscles in this area [1]. The most important clinical problem in MPS is trehalose-6-P synthase (TPs) [2], which are divided into active and inactive TPs [3]. According to Simon and Travell, problem in MPS is trigger points (TPs) characteristics include a hyper-sensitive spot in the bundle that produces referral and familiar pain pattern when stimulating a taut band, local twitch response, autonomic symptoms, and restricted range of motion (ROM). It is not necessary to have all of them [4].

It has been reported that TPs are the main problem in 30%-85% of musculoskeletal pain cases [5]. They are a chief complaint in 30% of the patients presenting to general internal medicine practice [6].

In a study investigating non-specific neck pain patients, trigger points existed in all cases and the trapezius muscles were the most involved muscle in 93.75% of the cases. Moreover, the highest number of trigger points was found near the horizontal fibers in the middle part of the upper trapezius (right 82.1% and left 79%) [7].

Although clinical diagnostic criteria are not equal to objective criteria, such as needle electromyography (EMG) [8], Gerwinetal reported the inter-rater reliability of the physical examination in some studies and purposed that physical examination was not reliable and had conclusion bias according to some review studies [9]. Mayoral del Moral reported that clinical criteria can be valid and reliable [8] but a trained examiner with adequate experience is essential to obtain valid and reliable results [10].

Although many theories exist, the exact pathophysiology of trigger points is not completely understood [11]. The integrated trigger hypothesis introduced by Simons includes an "energy crisis" owing to local injury by repetitive microtrauma that releases more ach and leads to sustained contracture of muscle fibers near an abnormal motor endplate, which increases local metabolic demands and applies over pressure on capillary circulation. By reducing the blood flow, the sarcomeres get to lock in hypercontraction [5, 12]. Recent studies have shown that neurogenic inflammation following central sensitization leads to the release of excess ach [12].

Many treatment techniques exist for trigger points, including invasive and non-invasive methods. Invasive treatment includes dry needling, acupuncture, and injection (anesthetic or anti-inflammation pharmaceuticals). Non-invasive treatment includes thermo therapy, laser therapies, electrotherapies, magnet therapies, ultrasound, and manual therapies [13].

Manual therapies include ischemic compression, spray and stretch, strain and counter-strain, muscle energy techniques, pressure release [14], and deep transverse friction massage (DTFM) [14, 15].

One of the most appropriate treatments for trigger points is ultrasound therapy [16, 17]. The high-power pain threshold ultrasound (HPPTUS) technique is one of the ultrasound modifications used to treat TPs [18]. The technique parameters include setting the frequency at 1 MHz in the continuous mode, increasing the intensity with a static probe until an uncomfortable sensation is reported, and then moving the probe around the trigger points [19, 20].

A recent systematic review showed that US therapy may probably have a significant effect on pain but rejected its effect on ROM [21]. Although some reviews questioned the effect of the US on MPS, they reported the probability of a high risk of bias [21-23] and the use of different parameters and settings of ultrasound therapy [21].

Few studies have compared the effect of HPPTUS and conventional US in patients with active trigger points of the neck. The results of two studies showed the superiority of the HPPTUS effects [19, 24] while the other showed no significant differences [25].

The effects of US have two aspects, non-thermal and thermal [26]. The HPPTUS technique places more emphasis on thermal effects. Following the increase in the temperature, the blood flow and extensibility of fibers increase too [27], and pain sensitivity and inflammatory substances decrease [26].

To determine the efficiency of HPPTUS, this study was conducted to compare it with deep transverse friction massage as a traditional technique [14, 15, 28] mentioned in several studies [15, 29-32]. Its mechanism of action includes ischemic compression as pressure treatment [33, 34], which is one of the most recommended noninvasive treatment options for cervical trigger points [35, 36]. Fernandez et al. compared the immediate effect of DTFM and ischemic compression on the upper trapezius TPs and found no significant difference in pain pressure threshold (PPT) and visual analog scale (VAS) improvement between the techniques [30].

To the best of our knowledge, no high-quality study has compared HPPTUS and DTFM.

In 1993, Hong et al. showed deep pressure soft tissue massage (described as friction massage) was more effective on PPT compared to thermal ultrasound [37]. In 2013, Hari Haran et al. found HPPTUS with transverse friction massage and static stretching was significantly more effective on pain and ROM of cervical lateral flexion (CLF) compared to transverse friction massage and static stretching [38].

The present study was conducted to compare the immediate effect of HPPTUS and DTFM as a traditional technique on upper trapezius active TPs in male patients with mechanical neck pain.

2. Materials and Methods

According to our previous study on HPPTUS, the sample size of 30 patients in each group [34] was calculated. Sixty patients with active trigger points in the upper trapezius (mean age: 30.57±6.19 years) participated in this single-blind clinical trial conducted at the clinic of the School of Rehabilitation between April 2017 and December 2019. Patients were referred by an orthopedic physician and trigger points were diagnosed by the experienced physical therapist.

The inclusion criteria included male gender, age 18 to 45 years, the existence of trigger point in hand preference, ability to perform active movements in the full ROM of abduction, scaption, and internal rotation of the shoulder, pain duration of more than 3 weeks, and the presence of only one TP in the upper trapezius muscle based on the following clinical findings:

-Touching a taut band inside the muscle.

-Presence of a hypersensitive point inside the taut band.

-A pain level of at least three according to the VAS scale in the initial evaluation.

-A referred familiar pain pattern when stimulating a taut band [19, 35, 36].

The exclusion criteria included a history of shoulder surgery or trauma (dislocation, replacement, joint sprain) in the last 6 months, history of chronic or acute diseases, such as neurological, cardiac, and metabolic diseases; skin lesions, infections or inflammation in the trigger point area, history of neck traumatic injury (e.g. whiplash injury), history of neck surgery, any malignancy or bad posture, fibromyalgia syndrome, use of corticosteroids, TP treatment in the past month, blindness and dyschromatopsia, use of any medication or history of any specific illness affecting cognition, consumption of caffeine before the test session, unfinished high school education [19, 35, 36].

After recording the initial evaluation information and marking the location of the trigger point by a physical therapist that was blind to treatment, the patients were randomly assigned to HPPTUS and DTFM groups [34, 39].

In the HPPTUS group, after explaining the procedure, the patient was placed in the prone position with the head in the neutral position and the hands placed next to the body. The ultrasound probe (Model: Ultrasound 620 p, Novin company) was placed on the TP (Figure 1). The frequency was set to 1 MHz, and the intensity increased from 0.5 to 2 w/cm^2 (the duty cycle 100%) until the patient reported an unpleasant sensation. The probe was held for 4; then, the intensity was reduced by 50%, and the probe was moved over and around the TP. This process was done several times over three minutes [26].

In the DTFM group, after explaining the procedure, the patient was placed in the prone position with the head in the neutral position and the hands placed next to the body. The force was applied using the fourth finger and reinforcement was done using the middle finger (Figure 2). The force was applied slowly and with little pain to the TPs of the upper trapezius muscle for three minutes [30].

After treatment, all values were re-evaluated by another physical therapist blinded to treatment [26, 36, 40].

Outcome measures

Visual analog scale

A VAS was used to evaluate pain. It was a 10-cm unmarked ruler with a range of no pain (zero) to the worst pain possible (ten). The patient placed a vertical line on the ruler considering his pain level. Then, the distance from the zero point to the marking was measured [26].

Pressure pain threshold

A pressure algometer (analog force gauge model: NK-500) was used to measure the PPT of TP. It consisted of a gauge attached to a cross-sectional area of 1 cm^2. The pressure was applied perpendicular to the desired point until the patient reported pain. The dial gauge was calibrated in kg/cm^2 ranging from 1 to 10 kg/cm^2. The pressure that caused the pain was recorded as PPT. In the present study, to measure PPT, the patient was placed in the prone position with the head in the neutral position and the hands placed next to the body (Figure 3). This test was performed three times with a time interval of 30 s. The average of three measurements was recorded [36].

Range of motion

A range of motion goniometer (baseline 360°) was used to measure the ROM of CLF. The patient was placed in a sitting position with a 90° flexion of the knee and thigh while the hands were resting on the thighs. The goniometer axis was placed on the spinous process of the seventh cervical vertebra. The fixed arm of the goniometer was perpendicular to the ground and its movable arm was placed parallel to the hypothetical vertical line of the head. To measure the range of motion, the head was placed at the anatomical position at the beginning of the movement and the ear approached the shoulder at the end of the movement (Figure 4). This test was performed 3 times for each point with a time interval of 30 s and the average of three measurements was recorded [26, 36, 40].

Statistical analysis

The data were analyzed using the SPSS software, version 22. As for descriptive statistics, Mean±SD were used for quantitative data. The Shapiro-Wilk test was applied to determine the normal distribution of the values and an independent t-test was used to assess the homogeneity of the primary data. Moreover, to evaluate the post-treatment changes, paired t-test was applied to the VAS of the HPPTUS group and the Wilcoxon test was applied to the PPT and ROM of CLF in the DTFM group and VAS, PPT, and ROM of CLF in HPPTUS. To compare inter-group value, the Mann-Whitney U test was used for values changes. To calculate the intragroup effect size, Cohen's d formula was used for VAS in the DTFM group, and the r formula (Wilcoxon effect size formula) was used for other values. For inter-group comparison, power was reported for VAS, and PPT and the effect size was reported for ROM of CLF.

To calculate the effect size, Cohen's d formula was applied to VAS in the HPPTUS group and the r formula (Wilcoxon effect size formula) was used for other values.

To assess correlation pre-test values and improvement values, Pearson and Spearman test were used based on parametric and nonparametric data.

3. Results

Sixty patients (age 30.57±6.19) participated in this study. Their baseline characteristics were homogenous according to t independent test (Table 1).

Table 2 presents the values of VAS, PPT, and CLF ROM before and after the intervention (Mean±SD, P, and effect size) (Table 2). VAS, PPT, and ROM of CLF increased significantly in both groups after the treatment (Table 2); however, a comparison of the two groups showed that only ROM of CLF improved significantly more in the HPPTUS group (Table 3).

According to Table 2, Cohen's d was above 0.8 [41] and r was above 0.5 [42] in the intragroup, and in the inter-group, according to Table 3, r formula was between 0.3 and 0.5 [42] for ROM and the power of test for VAS and PPT was below 0.8 [41-43].

An indirect correlation was observed between pre-treatment ROM and its improvement in both groups but in DTFM, an indirect correlation was observed between pre-treatment ROM and VAS improvement, and in the HPPTUS group, an indirect correlation was observed between pre-treatment VAS and ROM of CLF improvement (Table 4).

4. Discussion

This study was conducted to compare the immediate effect of HPPTUS and DTFM as a traditional technique on the treatment of active TPs in male patients with mechanical neck pain. The results showed that both techniques were effective. According to Table 2, the effect size of all values (Cohen's d>0.8 [41] , r>0.5 [42]) was large.

The immediate effect of HPPTUS has been reported in a few studies. Majlesi et al. found that VAS and ROM of CLF improved significantly after the first session of HPPTUS. Moreover, they found that the values improved after 1 session in 7 patients, after 2 sessions in 7 patients, after 3 sessions in 10 patients, and after 5 sessions in 12 patients. However, after each session, the patients performed active stretching of the trapezius muscle for 30 s five times. Nonetheless, the validity of the tool and the method that was used to measure the ROM were not evaluated [44]. Bahadir et al. reported that HPPTUS with active stretching significantly improved the VAS and ROM of CLF after one treatment session [20]. Unalan et al. reported that the mean number of treatment sessions in the HPPTUS group was 1.5 sessions [45]. Dhawan and Bhardwaj found that the

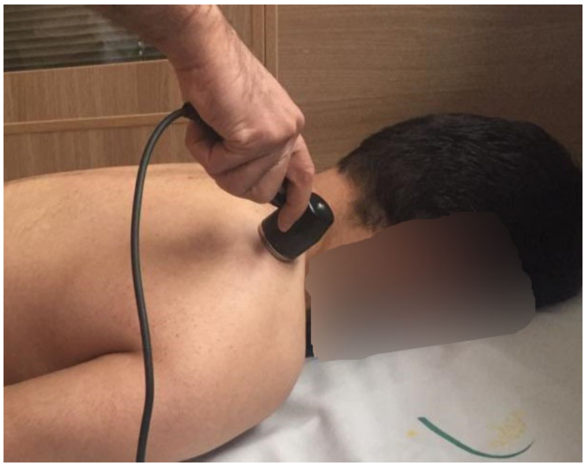

Figure 1. Patient position for applying HPPTUS

Figure 2. Patient position for applying DTFM

average pain reduction after one treatment session was 70% in the HPPTUS with stretching group. Aridici et al. reported that four HPPTUS sessions every other day significantly improved VAS and CLF [46].

Few studies have investigated the effect of HPPTUS on PPT. Kim et al. found a significant improvement in VAS after one week, in ROM of the cervical lateral flexion after three weeks, and in PPT after four weeks. Treatment was performed three times a week. ROM and PPT did not show a faster improvement, probably because the trigger points were inactive [47].

The exact mechanism of HPPTUS is not yet clear, but experiencing an unpleasant sensation during the technique and controlling it can reduce pain through the pain gate theory [26]. It has been reported that HPPTHS reduces the amplitude of the action potential, which is related to the thermal effects of the ultrasound [48]. In addition, increased ROM can be secondary to the reduction of pain and spasm associated with heat and biophysical effects, i.e. vasodilation, increased metabolism, reduced production of inflammatory substances, and increased tissue repair (for long-term effects) [44, 46].

The immediate effect of DTFM in this study was consistent with the results of a study by Fernández et al. that showed the immediate effect of deep transverse friction massage significantly improved VAS and PPT [33]. Similarly, Hong et al. showed that the immediate effect of deep friction massage on PPT of the active TPs of the upper trapezius muscle was greater than physiotherapy modalities [37].

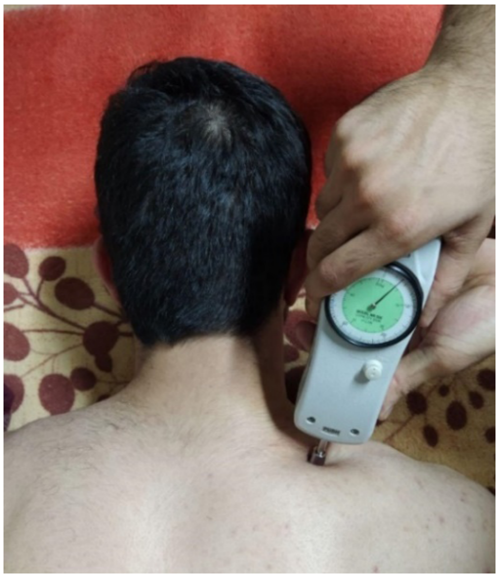

Figure 3. Algometry to assess pressure pain threshold

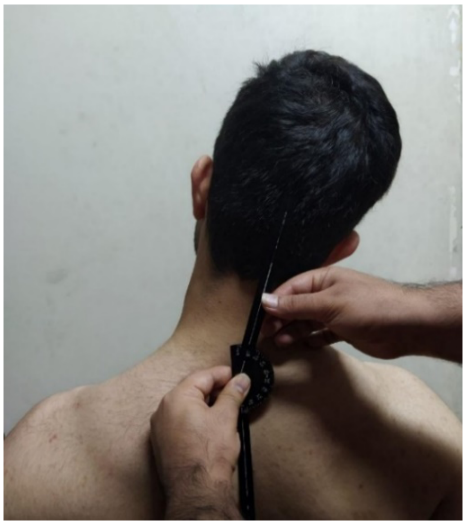

Figure 4. Goniometry to assess cervical lateral flexion

Table 1. Comparison of age and pre-intervention values between groups (independent t-test)

Variables	Mean±SD		P
	HPPTUS	DTFM	
Age (y)	32.14±5.86	29.00±6.22	0.057
VAS (cm) Pre-int	5.37±1.20	4.96±0.99	0.053
PPT (N/cm²) Pre-int	30.63±9.65	31.71±9.18	0.66
ROM⁷ (degree) Pre-int	30.34±6.78	33.41±5.17	0.062

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Abbreviations: HPPTUS: High-power pain threshold ultrasound; DTFM: Deep transverse friction massage; VAS: Visual anAlog scale: Pre-int: Pre-intervention; PPT: Pain pressure threshold; ROM: Range of motion.

It seems that the DTFM technique reduces pain by closing the pain gate and stimulating endorphin and ensefaline release, which blocks nociceptive neurotransmitters actions [49].

To our knowledge, few studies have investigated the effect of DTFM without additional treatment on the ROM of CLF in patients with TPs. Bukhari et al. found no difference between the effect of ischemic compression and friction massage on the ROM of CLF in the TPs of the neck and upper back. However, patients in both groups received a hot pack for 15 minutes before treatments, and primary evaluation was done after using a hot pack [50].

It was suggested that pain relief with pressure therapy may be adjusted due to hyperemia or reciprocal inhibition [49]. In the other study, Simons reported that pressure might adjust the length of sarcomeres mechanically [51]. Additionally, Hong et al. hypothesized that deep massage would stretch and mobilize the bundle of trigger points [37].

A comparison of the values between the two groups showed that the ROM of CLF increased significantly more in the HPPTUS group, which seems to be due to the thermal effects because HPPTUS effect is more base on thermal effects and it is applied to the area of trigger points and more surface of engaged muscle [27]. No significant difference was observed in the VAS and PPT between the two groups. However, due to the poor power of the test for VAS and PPT, it seems that studies with larger sample sizes are needed.

Our extensive search found no high-quality studies comparing HPPTUS and DTFM techniques. In 1993, Hong et al. showed the greater effect of deep-pressure soft tissue massage (described as friction massage) on PPT compared to thermal ultrasound for 5 minutes. However, deep-pressure soft tissue massage was a two-technique adjustment of ischemic compression and connective tissue massage. It was performed with the middle finger of both hands and was reinforced with the other two fingers for 10-15 minutes, which could explain the differences in our results [37].

Table 2. Comparison of values before and after treatment in both groups (paired t-test and Wilcoxon (n=30)

Variables		HPPTUS			DTFM		
		Mean±SD	P	Effect Size	Mean±SD	P	Effect Size
VAS (cm)	Pre-Int Post-Int	5.37±1.20 2.79±1.33	<0.001	2.04	4.68±0.99 1.95±1.26	<0.001	0.58
PPT (N/cm²)	Pre-Int Post-Int	30.63±9.65 44.67±15.13	0.001	0.59	31.71±9.18 45.83±8.87	<0.001	0.59
ROM (degree)	Pre-Int Post-Int	30.34±6.78 39.70±4.58	<0.001	0.54	33.41±5.17 37.24±3.55	<0.001	0.56

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Abbreviations: HPPTUS: High-power pain threshold ultrasound; DTFM: Deep transverse friction massage; VAS: Visual analog scale; Pre-int: Pre-intervention; Post-Int: Post-intervention; PPT: Pain pressure threshold; ROM: Range of motion.

Table 3. Comparison of improvement values mean between groups (n=30)

Variables	Statistical Test	P	Effect Size	Power
VAS (cm)	Mann–Whitney U	0.54	0.63	0.07 (power)
PPT (N/cm²)	Mann–Whitney U	0.88	0.1	0.31 (power)
ROM (degree)	Mann–Whitney U	<0.01	0.45 (effect size)	0.8

Abbreviations: VAS: Visual analog scale; PPT: Pain pressure threshold; ROM: Range of motion.

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Hari Haran et al. found HPPTUS with transverse friction massage and static stretching was significantly more effective on NPRS, NPDI, and ROM of CLF compared to transverse friction massage and static stretching for 4 weeks, two sessions per week [38].

An indirect correlation was observed between pre-treatment ROM and its improvement in both groups but in DTFM, an indirect correlation was observed between pre-treatment ROM and VAS improvement which is clinically important. Patients with less ROM experienced more improvement in the VAS and ROM while in the HPPTUS group, an indirect correlation was observed between pre-treatment VAS and ROM of CLF improvement which indicate patients with more pain experienced less ROM of CLF improvement.

According to our literature search, most studies used DTFM for three minutes or more and then evaluated the treatment effect of the technique [33, 37, 38, 50]. Trampas et al. used the DTFM technique on latent hamstring trigger points, in less than the 90 s, which resulted in ROM and VAS improvement in the group undergoing DTFM and modified stretching compared to the modified stretching group. Although no significant difference was observed in PPT improvement between the groups, it only improved significantly in the combination group compared to the control group [52]. Mohamadi et al. [31] used the protocol suggested by Trampas et al. [52] and the results showed significant improvement in PPT and grip strength in latent TPs in the upper trapezius. It seems the point of considering pain in the study by Mohamadi et al. [31] and free pain applied in the study by Trampas et al. [52] (melting taut band session) can be the reason for different results.

Since it was essential to compare HPPTUS and DTFM in similar conditions, we decided to apply treatment for 3 minutes [41] in both groups moved the applicator for 30 s to avoid probable side effects (maximum time described [26]). However, subjects in the HPPTUS group received a different repetition of the technique (the difference was not more than 1).

Most of the studies repeated the HPPTUS technique three times and applied the treatment for less than 2 minutes in one session, and reported the treatment effects of HPPTUS in MPS. However, Vieira Dibai-Filho et al. used static ultrasound for 3 minutes in a continuous mode at 1 MHz with 1.5 w/cm intensity (fixed) and showed that the technique accompanied by manual therapy had no additional effects compared to manual therapy alone [53]. In the present study, all patients reported an uncomfortable sensation less than 20 s after using the applicator. The ultrasound mark can explain the differences in duration and results. Kim et al. used the HPPTUS technique with five repetitions for less than 5 minutes on inactive trigger points. However, experience and information exchange between the patient and therapist are essential for using HPPTUS [47].

Table 4. Assessing correlation between pre-test and improvement values (Pearson and Spearman)

Groups	Variables	Statistical Test	Correlation Coefficient	P
HPPTUS	VAS and ROM-Imp (cm) ROM and ROM-Imp	Pearson Pearson	-0.403 -0.763	0.034 <0.01
DTFM	ROM and VAS-Imp ROM and ROM-Imp (degree)	Spearman Spearman	-0.574 -0.664	<0.01 <0.01

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Abbreviations: HPPTUS: High-power pain threshold ultrasound; DTFM: Deep transverse friction massage; VAS: Visual analog scale; ROM: Range of motion; ROM-Imp: Range of motion-improvement; VAS-Imp: Visual analog scale improvement.

Some contraindications reported for HPPTUS include peripheral vascular disease, regions with sensitivity impairment to heat or pain, areas adjacent to nerve laminectomy segments, heart failure, and precancerous states [54].

The limitations of this study include its small sample size, recruiting only male patients, lack of a long-term follow-up, lack of a placebo group, and complexity of proper communication regarding the HPPTUS technique which requires experiences and detailed explanation.

Since DTFM puts a lot of pressure on the physiotherapist's fingers and in this study, HPPTUS was more effective than DTFM, it is suggested that HPPTUS could be one of the choice of protocol treatment of trigger points.

5. Conclusions

HPPTUS and DTFRM are effective treatments for upper trapezius active TPs in male patients with mechanical neck pain. It seems that HPPTUS is more effective than DTFM.

Avenues for future research

We suggest larger studies with long-term follow-up times, an equal number of male and female patients, comparing long-term and combination effects of both groups, fixing the number of HPPTUS repetitions, evaluating functional changes of patients in each group, and evaluating other muscle trigger points.

Ethical Considerations

Compliance with ethical guidelines

All procedures performed in studies involving human participants by the ethical standards of the Ethics Committee of the Tehran University of Medical Sciences and the study protocol (Code: IR.TUMS.VCR.REC.1398.903) was approved by the Ethics Committee of Tehran University of Medical Sciences and informed consent was obtained from all participants.

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Authors' contributions

Conceptualization, study design and final approval: All authors; Data collection: Mehrdad Sadeghnia; Data analysis and data interpretation: Shohreh Jalaei; Drafting the manuscript: Mehrdad Sadeghnia and Saman Salehi.

Conflict of interest

The authors declared no conflict of interest.

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