P-ISSN 2586-9000
E-ISSN 2586-9027
Homepage : *https://tci-thaijo.org/index.php/SciTechAsia* **Science & Technology Asia**
Vol.29 No.3 July - September 2024 Page: [304-314]
Original research article

The Immediate Effects of Conventional and High-Power Pain Threshold Ultrasound on Myofascial Pain Syndrome among Young Thai Adults

Sukwida Manorangsan*

Department of physical therapy, Faculty of Allied Health Sciences, Thammasat University, Pathum Thani 12120, Thailand

Received 18 January 2024; Received in revised form 12 August 2024
Accepted 2 September 2024; Available online 25 September 2024

ABSTRACT

The study aimed to compare the immediate effects of conventional ultrasound (Con-US) and high-power pain threshold ultrasound (HPPT-US) on pain and neck range of motion (ROM) in young Thai adults with active trigger points of myofascial pain syndrome (MPS). Sixty participants were randomly allocated into two groups: Con-US (mean age 20.97±1.16 years) and HPPT-US (mean age 21.47±1.28 years). Each group underwent a single ultrasound session lasting 5 minutes. Parameters assessed pre- and post-treatment included pain intensity, neck ROM, pressure pain threshold (PPT), and pressure pain tolerance (PPTo). The average intensity dose for Con-US was 1.0 W/cm^2, while for HPPT-US it was 0.83 W/cm^2. Both techniques improved pain parameters, but there was no significant interactive effect between group and time. The single moderate-intensity session of HPPT-US may not have a lasting impact on pain tolerance due to the lack of a cumulative effect. Further studies with increased treatment sessions and higher intensity ultrasound are recommended.

Keywords: High-power pain threshold ultrasound; Myofascial pain syndrome; Pressure pain threshold; Ultrasound

1. Introduction

Myofascial pain syndrome (MPS) is a condition characterized by muscle pain, limited range of motion (ROM), and health impacts caused by sensitive trigger points (TrPs), taut bands, and referred pain to other areas. In clinics, the prevalence of MPS is typically found to be approximately 30%, with 85% of affected individuals experi-

***Corresponding author:** sukwida.m@allied.tu.ac.th **doi:** xx.xxxxx/scitechasia.xxxx.xx

encing pain and TrPs located in the upper trapezius muscle [1, 2]. Neck-shoulder pain was observed in 42-46% of Thai undergraduate students, with the musculoskeletal disorder primarily related to poor posture and prolonged computer use; additionally, 33% of individuals reported continuing neck pain during the one-year follow-up [3, 4]. Active TrPs can cause pain both during rest and muscle activity, whereas latent TrPs only produce pain when pressure is applied. However, if latent TrPs are repeatedly stimulated, they may transition into active TrPs [2].

There are various techniques for treating MPS, the most frequent of which is ultrasound therapy which is effective, and does not have side effects [5]. According to a previous study, using conventional ultrasound (Con-US) therapy to treat MPS can significantly reduce pain in the upper trapezius muscle. Con-US's thermal effect raises tissue temperature, increases tissue elasticity and reduces pain [6-8]. Additionally, ultrasound has the potential to alleviate pain, increase the pain threshold, and inhibit the release of acetylcholine from motor endplates, resulting in muscle relaxation [6,9-11] In physical therapy clinics, Con-US is frequently utilized to reduce the pain intensity from MPS . Meanwhile, some research has shown that increasing the pain threshold in cases of MPS using high-power pain threshold ultrasound (HPPT-US) can reduce the number of physical therapy sessions needed [12-14].

From a previous meta-analysis and systematic review, it was shown that the use of physical therapy modalities may increase the pressure pain threshold (PPT) in the upper trapezius muscle; however, the PPT in this muscle remains lower than that of healthy tissue [11]. Applying high-intensity US results in significantly increased PPT for the trapezius TrP when compared with low-intensity US [10]. In a study by Srbely JZ and Dickey JP, it was reported that the intervention group's PPT at the trapezius TrP site increased by 44.1 (14.2%), 15.8±SD 5.1, N) on average, while controls recorded a mean increase of only 1.4 (12.2%), 0.5±SD 4.5, N) after ultrasound exposure (p<0.05). Moreover, there was no difference between pre- and post-treatment for PPT in the control group [10]. In addition, several studies have shown that the gradual increase in intensity level to the maximum pain threshold using HPPT-US may be more effective than Con-US for improving PPT scores and reducing the number of treatment sessions required [12-14]. Notably, a previous study reported that using the HPPT-US technique and repeating it for a total of three times was more effective than using the Con-US technique in terms of improving the VAS, PPT, and cervical ROM in individuals aged 18-60 years who had active TrPs [12, 13]. Additionally, Kim et al. reported that HPPT-US with nine repeated rounds was more effective than HPPT-US with five repeated rounds and Con-US for reducing the VAS and PPT in elderly individuals with latent TrPs [14]. In contrast, another study revealed no differences for VAS, PPT, and ROM when comparing the HPPT-US technique with three repeated rounds and the Con-US technique for MPS with latent TrPs in older individuals [15]. Consequently, the HPPT-US technique did not prove to be more effective than the Con-US technique.

As previously mentioned, HPPT-US is an alternative treatment for MPS that can provide longer-lasting pain relief and improvements in pain levels, PPT, and ROM, compared to Con-US therapy. In Thailand, Con-US with varying levels of intensity is the most commonly used physical therapy

treatment for MPS. It can be used generally in clinics for MPS, however there is a lack of evidence to determine whether the effect of the HPPT-US technique used in young Thai adults with MPS can reduce pain and to improve neck ROM. HPPT-US could be an option for physical therapy in patients with MPS that could maximize therapeutic effects, further optimize outcomes, reduce the frequency of treatment visits, and may help reduce costs and treatment durations. Therefore, this study aimed to compare the immediate effects of Con-US and HPPT-US in young Thai adults with MPS. We hypothesized that, compared to Con-US, HPPT-US would result in a greater reduction in pain and a larger improvement in neck ROM in young Thai adults with MPS.

2. Materials and Methods

This research protocol was approved by The Human Research Ethics Committee of Thammasat University (Sciences). The number of Certificate of Approval is 019/2562. The study design is cross-section study.

2.1 Participants

Sixty university students, male and female, aged 18-25 years were diagnosed with MPS by a physical therapist (PT) who had clinical experience of more than 10 years, according to the criteria proposed by Simon and Travell [2]. This sample size of 60 was calculated using G-power version 3.1.9.2, referring to an effect size of $d = 2.96$ based on a previous study which compared VAS after treatment [12]. The researcher explained the objectives and the entire protocol to participants, then all individuals provided written informed consent before starting data collection. The inclusion criteria were as follows: (1) aged 18-25 years, (2) body mass index (BMI) ranging 18-23 kg/m2, (3) at least 6-8 hours/day of working in a sitting position, (4) diagnosed chronic MPS with at least one active TrP at the upper trapezius muscle for at least 6 months, and (5) no other treatment at the upper trapezius muscles for at least 1 month. The exclusion criteria were as follows: (1) having abnormal sensations or symptoms related to the central nervous system and peripheral nerves, (2) presence of radiculopathy or myelopathy of the shoulder/neck, (3) history of cervical or shoulder/neck surgery, (4) having had an x-ray in the previous week, and (5) history of venous thromboembolism. The whole protocol is presented in Fig. 1.

2.2 Procedures

All participants were assessed for active TrPs in the upper trapezius muscle to determine the area requiring ultrasound treatment. This was a double-blind study in which both the participants and the assessor were unaware of the treatment method used. Using opaque envelopes sealed by the same PT, the participants were randomly allocated into either the Con-US group ($n = 30$) or the HPPT-US group ($n = 30$). Pain and ROM were assessed pre- and post-US treatment by another researcher who was unaware of the treatment group. Additionally, all US interventions were performed by a second PT, who was involved in therapeutic treatment only and was not aware of the participants' details.

2.3 Measurements

In this study, the independent variable was treatment method (Con-US vs. HPPT-US), while the dependent variables included pain intensity as indicated by the VAS, PPT, pressure pain tolerance (PPTo), and the lateral neck flexion ROM. All parameters were evaluated pre- and post-US treatment.

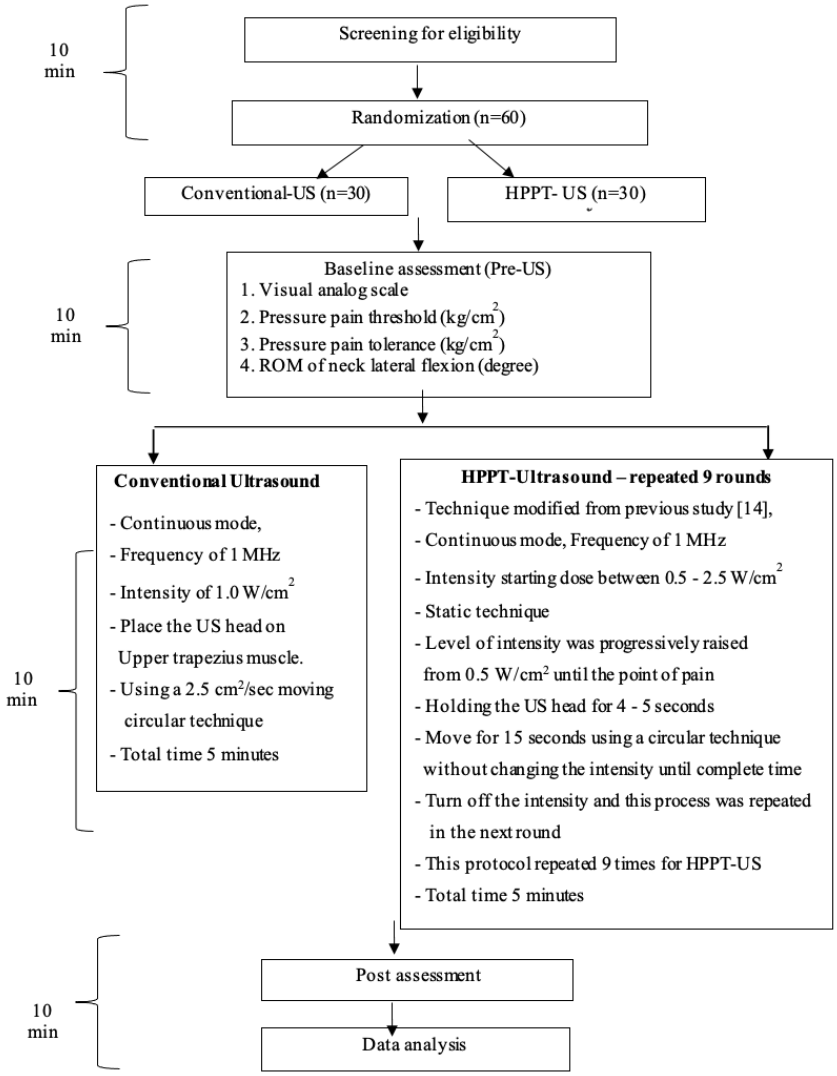


Fig. 1. Flow diagram of study protocol.

Regarding the treatment process, participants began in the starting position, sat on a chair with a backrest. Subsequently, a pressure pain algometer (FPX; Wagner Instruments, USA), a digital pain scale with high reliability and validity [16], was applied to measure pain intensity (VAS), PPT, and PPTo on the TrPs of the upper trapezius muscle as shown in Fig. 2. VAS was measured with an applied force of 4.5 kg/cm^2 from the pain algometer on the TrP [14], and the assessor requested that the participants report pain intensity from 0 (no pain at all) to 10 (high pain). This was repeated for three trials, with a short break of 60 seconds in between each trial. Moreover, to measure the PPT, the assessor applied pressure to the TrP of the upper trapezius muscle until the participants felt pain. The assessor then recorded the quantity of pain pressure in kg/cm^2. In addition, to measure PPTo, the assessor applied more force over the TrP

of the upper trapezius muscle until the participants could not withstand the pressure, and reported the number obtained from pain algometer in kg/cm^2. The intraclass correlation coefficient (ICC) for the PPT assessor was ICC = 0.945, prior to the intervention time, indicating test-retest reliability.

Furthermore, the neck lateral flexion ROM was measured using a universal goniometer with a high reliability [17]. The participants were asked to move their head to the opposite side through end of neck lateral flexion, and the goniometer was placed on the spinous process of C7, with a stationary arm placed in line with the thoracic spine and a movable arm pointed up in the line of the occipital protuberance. The test-retest reliability of the assessor was ICC=0.886 before the intervention time, and this protocol was measured three times with 1-minute intervals.

2.4 Intervention Group1: Con-US

Con-US was performed using a Chattanooga device (Intelect Advanced, USA) with a 5 cm2 head diameter (effective radiation area of 5 cm2) at a frequency of 1 MHz. The device was used in the continuous mode, with an intensity of 1.0 W/cm2 at active TrPs on the upper trapezius muscle, using a 2.5 cm2/sec moving circular technique for 5 minutes. A diagram of the procedure is presented in Figure 1.

2.5 Intervention Group 2: HPPT-US

An HPPT-US technique modified from a previous study [14] was used, which was performed using the same US device at a frequency of 1 MHz in the continuous mode, and the intensity ranged from 0.5-2.5 W/cm^2 at the active TrPs of the upper trapezius muscle. Before initiating the treatment, the PT needed to communicate with the participant to obtain feedback regarding how they felt while starting the US dose for the HPPT-US technique. The US device's head was placed using the static technique and initiated with a starting dose of 0.5 W/cm^2. Subsequently, the level of intensity was progressively raised from 0.5 W/cm^2 to the point of pain threshold. At this point, the US head was held for 4-5 seconds, and the probe was then moved for 15 seconds using a circular technique, without changing the intensity until the completion time. The intensity was then turned off, and this process was repeated in the next round. This protocol was repeated nine times, and the duration of the HPPT-US technique was approximately 5 minutes. The diagram of this procedure is displayed in Fig. 1.

All parameters, including pain and neck lateral flexion ROM, were evaluated following the completion of the US technique. These tests were performed three times in total, and the average of these measures was used for data analysis.

2.6 Statistical analysis

All data were analyzed using IBM SPSS Statistics 22. Descriptive statistics are expressed as mean and standard deviation for all variables. Shapiro-Wilk test was used to assess the distribution of the data. The unpaired t-test or the Mann-Whitney U test was used for comparisons between the groups. Pain and ROM were initially compared using a two-way mixed ANOVA. The main effects were treatment group, and time (pre- and post-US treatment). Interaction effects were examined for significance between treatment group and time. Post hoc pair-wise comparisons were then performed with t-tests. The level for statistical significance was set at $p < 0.05$.

2.7 Ethical approval

The research involving humans complied with all relevant national regulations, institutional policies and was performed in

accordance with the tenets of the Helsinki Declaration, CIOMS guidelines, and the International practice (ICH-GCP) and has been approved by The Human Research Ethics Committee of Thammasat University (Science), (HREC-TUSc) with Certificate of Approval (COA No. 097/2562).

3. Results and Discussion

3.1 Baseline characteristics

In this study, 60 participants with MPS were randomly assigned into two groups to undergo either Con-US (n=30; 29 women, 1 man) or HPPT-US (n = 30; 28 women, 2 men). No significant differences were found in the baseline characteristics such as age, body mass, height, BMI, and symptom onset. In addition, there were no significant differences in the pain intensity (VAS), PPT, PPTo, and lateral neck flexion ROM between the groups before undergoing the ultrasound technique, as shown in Table 1).

3.2 Immediate effect of ultrasound treatment on pain and neck ROM within groups

Two-way mixed ANOVA showed time (pre-post) to be the only significant effect. At post-treatment, both the Con-US and HPPT-US techniques resulted in improvements in pain parameters, including pain intensity ($F = 52.662$, $p < 0.001$), PPT ($F = 7.436$, $p = 0.008$), PPTo ($F = 6.474$, $p = 0.014$), and neck ROM ($F = 66.254$, $p < 0.001$). However, there were no significant interactive effects between group and time which revealed no differences between the two techniques, as indicated in Table 2.

3.3 Comparison of pain and neck ROM between Con-US and HPPT-US

The average intensity used in the Con-US group (1.0 W/cm^2) was higher than in the HPPT-US group which had a mean of 0.83±0.19 W/cm^2 and an intensity range of 0.5-1.2 W/cm^2.When comparing pain and neck ROM between the groups, results indicated that the Con-US technique had a greater improvement in pain intensity (VAS), PPT, and ROM than the HPPT-US technique had, but there was no interaction effect between group and time which displayed no differences between groups as illustrated in Tables 2-3.

3.4 Discussion

This study aimed to compare the immediate effects of Con-US and HPPT-US techniques on pain and ROM in young adults who have MPS with active TrPs. There were no significant differences in age, BMI, symptom onset of MPS, pain intensity, and neck ROM between the groups. Therefore, the participants in the groups may have had similar characteristics at baseline.

3.4.1 Pain intensity (VAS)

Notably, our results showed that the two ultrasound techniques could immediately reduce pain intensity at active TrPs of the upper trapezius muscle. The possible mechanisms underlying this effect may include the thermal effect of US, which results in vasodilation and increased blood flow to the low-oxygen injury area, removing the substances causing pain, as well as the deactivation of chemosensitive pain receptors, leading to decreased pain intensity [8, 9, 19, 20]. Although we showed that US treatment reduces pain intensity, there were no significant differences between the Con-US and HPPT-US techniques. This study revealed that the Con-US technique was more effective in reducing pain than the HPPT-US technique. This may be due to the average intensity used in the Con-US group (1.0 W/cm^2) being higher than

Table 1. Baseline characteristics of participants.

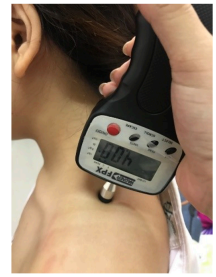
Characteristics	Con-US Group (n = 30)	HPPT-US Group (n = 30)	p-value
Age (yrs.), mean (SD)	20.97 (1.16)	21.47 (1.28)	0.118a
Weight (kg), mean (SD)	56.02 (8.49)	55.23 (7.15)	0.700a
Height (cm), mean (SD)	163.53 (8.22)	161.4 (7.72)	0.304a
BMI (kg/m2), mean (SD)	20.83 (1.68)	21.14 (1.53)	0.459a
Symptom onset (month), mean (SD)	17.03 (12.9)	22.77 (18.25)	0.165a
Pain intensity (VAS); mean (SD)	3.63 (1.61)	3.33 (1.47)	0.408b
Neck ROM (degree), mean (SD)	24.93 (4.56)	25.67 (7.35)	0.644a
PPT (kg/cm2), mean (SD)	2.28 (0.85)	2.45 (1.26)	0.877b
PPTo (kg/cm2), mean (SD)	5.13 (1.73)	5.49 (2.43)	0.701b

VAS= Visual analog scale; ROM= lateral neck flexion ROM; PPT= Pressure pain threshold; PPTo= Pressure pain tolerance; aunpaired t-test; bMann-Whitney U test.

Table 2. Two-way mixed ANOVA compare between group and time treatment.

Dependent variables	Source of variances		Mean	SD	Within-subjects		Between-subjects		Interaction effect	
	Group	Time			*F*	*p-value*	*F*	*p-value*	*F*	*p-value*
Pain (VAS)	Con-US	pre	3.63	1.61	52.662	<0.001	0.020	0.887	3.917	0.053
		post	2.00	1.46						
	HPPT-US	pre	3.33	1.47						
		post	2.40	1.52						
Neck ROM	Con-US	pre	24.93	4.56	66.254	<0.001	0.179	0.674	0.051	0.823
		post	28.47	5.24						
	HPPT-US	pre	25.67	7.35						
		post	29.01	6.73						
PPT	Con-US	pre	2.28	0.85	7.436	0.008	0.117	0.733	0.310	0.580
		post	2.67	1.35						
	HPPT-US	pre	2.45	1.26						
		post	2.71	1.42						
PPTo	Con-US	pre	5.13	1.73	6.474	0.014	0.662	0.419	0.157	0.694
		post	4.74	1.55						
	HPPT-US	pre	5.49	2.43						
		post	5.20	2.30						

(a) Pressure pain algometer (FPX; Wagner, USA)



(b) Pain measured at Trapezius muscle

Fig. 2. Pressure pain algometer and pain measurement.

that used in the HPPT-US group which had an average intensity of 0.83±0.19 W/cm^2 and an intensity range of 0.5-1.2 W/cm^2 for HPPT-US participants. The intensity

Table 3. Summary of findings on pain and neck ROM between Con-US and HPPT-US.

Parameters	Immediate effects Con-US (post - pre)	Immediate effects HPPT-US (post - pre)	Comparison between group
Visual analog scale	Improved	Improved	No difference
Neck ROM	Improved	Improved	No difference
Pressure Pain Threshold	Improved	Improved	No difference
Pressure Pain Tolerance	Decline	Decline	No difference

level used in our study is classified as a moderate intensity (0.8-1.5 W/cm^2) which was reported from previous evidence [9, 13]; therefore, this may explain the lack of differences in pain reduction between the two techniques. Similarly, a previous study [15] reported no difference between the moderate-intensity HPPT-US (0.5-1.5 W/cm^2) (three rounds) and Con-US (1.0 W/cm^2) techniques with regard to pain relief in the upper trapezius muscles of elderly individuals with latent myofascial TrPs.

3.4.2 Pressure pain threshold (PPT) and Pressure pain tolerance (PPTo)

In this study, we also found that the PPT was increased following US treatment. Notably, the mean difference between the pre- and post-US PPT was higher in the Con-US group (0.39±0.94 kg/cm^2) than in the HPPT-US group (0.26±0.91 kg/cm^2). This difference may be due to the higher thermal effect of ultrasound in the Con-US group, since its mean intensity was higher than that of the HPPT-US group. The thermal effect may increase the pain threshold by stimulating the nerve conduction velocity of large fibers sending signals to inhibit pain excitation (C fibers), resulting in blocked pain transmission to the spinal cord [7, 8, 11]. Thus, both Con-US and HPPT-US could increase the threshold of pain.

In contrast, previous studies have reported a higher increase in the PPT following HPPT-US than when using the Con-US technique, and that these effects remain long term [13, 14]. In fact, Koca et al. reported that HPPT-US with a maximum dose (1.5-2.5 W/cm^2) increased PPT more than Con-US did (1.5 W/cm^2) when used on active TrPs for 10 sessions over 2 weeks [13]. Another study reported that HPPT-US with nine rounds increased PPT more than HPPT-US with five rounds and Con-US with three rounds per week [14]. Therefore, it may be possible to increase the PPT immediately after US treatment and over the follow-up period by using a higher dose and number of treatment sessions; the present study did not investigate this but it could be an area for future research.

Furthermore, our study showed that PPTo was decreased after immediate treatment; since this study protocol was conducted only once, the intensity and number of treatment sessions were insufficient to induce pain habituation and there was no cumulative effect. In contrast, Kim et al. reported that HPPT-US with nine rounds (three sessions per week) resulted in a greater increase in PPTo than when using Con-US in elderly subjects with latent TrPs [14]. In fact, previous research has shown that the HPPT-US technique induces pain habituation by repeatedly stimulating pain, ultimately leading to an increased pain tolerance [21, 23]. That repeated stimulation of pain may involve an underlying mechanism in which brain activity is triggered, sending a signal through the dorsolateral

funiculus of the dorsal horn of the spinal cord. This process can lead to the release of endogenous opiates, which inhibit pain-transmitting neurons and ultimately result in an increased pain threshold and tolerance [24].

3.4.3 Range of motion of the neck

In this study, we also showed that ultrasound treatment could immediately increase the neck lateral flexion ROM in subjects who have chronic MPS with active TrPs. The increased tissue temperature caused by the thermal effect of US can lead to various effects, including increased flexibility, the dilation of blood vessels, reduced viscosity, and altered elasticity of collagen tissues. Consequently, these changes can result in tissue softening and promote muscle relaxation [8, 9]. Additionally, heat inhibits the action of acetylcholine at the motor endplate, resulting in muscle relaxation and pain relief [2]. Therefore, the two US techniques used in this study may lead to an increase in neck lateral ROM through this mechanism. Furthermore, Morishita et al. reported that the thermal and mechanical effects of US with a dose of 1.0 W/cm^2 could increase the intramuscular oxygenation levels, total hemoglobin levels, and skin temperature [25]. These effects may act to improve muscle flexibility in healthy adults aged 20-39 years. In fact, Saime et al. demonstrated an improvement in neck lateral flexion motion in individuals aged 20-73 years who underwent US treatment for MPS, with an intensity ranging 1-1.5 W/cm^2 [26].

However, in this study, there were no differences in neck ROM between the HPPT-US and Con-US techniques for MPS with active TrPs. This may be due to the similar therapeutic effects of comparable US intensity levels, as well as the small number of US treatment sessions performed in this study. This corresponds with a previous study reporting that HPPT-US with three rounds increased neck ROM to a higher extent than Con-US (1.0 W/cm^2) in elderly subjects with active TrP; however, the difference between the two techniques was not significant [15]. Similarly, Majlesi and Unalan reported that HPPT-US was significantly more effective than Con-US at increasing neck ROM in patients with active TrPs at the upper trapezius muscles [12]. The success of this previous study may have been due to the multiple treatment sessions conducted within one year, resulting in better tissue relaxation and increased neck movement [12]. Therefore, it is possible that our study's limitation of performing only one session may not have allowed for the long-term cumulative effects of HPPT-US treatment to take place.

3.5 Limitations

The study had some limitations. First, ultrasound therapy was only conducted once at a medium dose; therefore, it may not have had an accumulative effect. Additionally, there was a lack of long-term evaluation after the completion of US treatment.

4. Conclusion

This study revealed that a single moderate-intensity Con-US treatment session can effectively reduce pain intensity, pressure pain threshold, and improve neck range of motion in individuals who have chronic MPS with symptom onset of over 6 months, which has potential clinical implications. These outcomes were comparable to the results obtained from the HPPT-US technique for active trigger points; however, there were no differences between the Con-US and HPPT-US treatment groups.

For enhanced long-term efficacy in managing MPS, future research should focus on increasing the number of HPPT-US treatment sessions and exploring higher intensity levels. This approach is expected to maximize therapeutic effects, further optimize the outcomes of HPPT-US treatment for MPS, and reduce the frequency of treatment visits.

References

[1] Dommerholt J, Simons DG. Myofascial pain syndrome-trigger points. J Musculoskeletal Pain, 2008;16:211-8.

[2] Simons DG, Travell JG, Simons LS. Travell & Simons' myofascial pain and dysfunction: The trigger point manual. Volume 1: Upper half of body. 2nd ed. Baltimore, MD: Williams and Wilkins; 1999. p 278-307.

[3] Kanchanomai S, Janwantanakul P, Pensri P, Jiamjarasrangsi W. Risk factors for the onset and persistence of neck pain in undergraduate students: 1-year prospective cohort study. BMC Public Health, 2011;11:566.

[4] Parinya Lertsinthai, Jutharat Nontakoot, Nattha Toudkavinkul, Aritsara Weerachai, Opor Weeraphan. The prevalence of neck pain and the relationship between neck pain and computer vision syndrome in Faculty of Allied Health Sciences students at Naresuan University. Thai J Phys Ther, 2020; 42(2): 101-17.

[5] Qing W, Shi X, Zhang Q, Peng L, He C, Wei Q. Effect of therapeutic ultrasound for neck pain: A systematic review and meta-analysis. Arch Phys Med Rehabil, 2021;102(11):2219-30.

[6] Yildirim MA, Ones K, Goksenoglu G. Effectiveness of ultrasound therapy on myofascial pain syndrome of the upper trapezius: Randomized, single-blind, placebo-controlled study. Arch Rheumatol, 2018;33(4):418-23.

[7] Kavadar G, Caglar N, Ozen S, Tutun S, Demircioglu D. Efficacy of conventional ultrasound therapy on myofascial pain syndrome: A placebo-controlled study. Agri, 2015;27(4):190-6.

[8] Draper DO, Mahaffey C, Kaiser D, Eggett D, Jarmin J. Thermal ultrasound decreases tissue stiffness of trigger points in upper trapezius muscles. Physiother Theory Pract, 2010;26(3):167-72.

[9] Saber AA, Saber A. Therapeutic ultrasound: Physiological role, clinical applications and precautions. J Surg, 2017;5(3):61-9.

[10] Srbely JZ, Dickey JP. Randomized controlled study of the antinociceptive effect of ultrasound on trigger point sensitivity: Novel applications in myofascial therapy? Clin Rehabil, 2007;21(5):411-7.

[11] Geri T, Botticchio A, Rossettini G, Pournajaf S, Pellicciari L, Di Antonio S, Castaldo M. Pressure pain threshold of the upper trapezius trigger point: A systematic review with meta-analysis of baseline values and their modification after physical therapy. J Clin Med, 2022;11(23):7243.

[12] Majlesi J, Unalan H. High-power pain threshold ultrasound technique in the treatment of active myofascial trigger points: A randomized, double-blind, case-control study. Arch Phys Med Rehabil, 2004;85(5):833-6.

[13] Koca I, Tutoglu A, Boyaci A, Ucar M, Yagiz E, Isik M, et al. A comparison of the effectiveness of low-, moderate- and high-dose ultrasound therapy applied in the treatment of myofascial pain syndrome. Mod Rheumatol, 2014;24(4):662-6.

[14] Kim Y, Kim J, Kwak K, Yoon B. A preliminary study on the effect of high-power pain threshold ultrasound to desensitize latent trigger points: A double-blinded

randomized study. J Musculoskelet Pain, 2014;22(2):175-81.

[15] Kim Y, Yang HR, Lee JW, Yoon BC. Effects of the high-power pain threshold ultrasound technique in the elderly with latent myofascial trigger points: a double-blind randomized study. J Back Musculoskelet Rehabil, 2014;27(1):17-23.

[16] Walton DM, Macdermid JC, Nielson W, Teasell RW, Chiasson M, Brown L. Reliability, standard error and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain. J Orthop Sports Phys Ther, 2011;41(9):644-50.

[17] Farooq MN, Mohseni Bandpei MA, Ali M, Khan GA. Reliability of the universal goniometer for assessing active cervical range of motion in asymptomatic healthy persons. Pak J Med Sci, 2016;32(2):457-61.

[18] Nacitarhan V, Elden H, Kisa M, Kaptanogglu E, Nacitarhan S. The effects of therapeutic ultrasound on heart rate variability: A placebo-controlled trial. Ultrasound Med Biol, 2005;31(5):643-8.

[19] Saxena A, Chansoria M, Tomar G, Kumar A. Myofascial pain syndrome: an overview. J Pain Palliat Care Pharmacother, 2015;29(1):16-21.

[20] Ilter L, Dilek B, Batmaz I, Ulu MA, Sariyildiz MA, Nas K, Cevik R. Efficacy of pulsed and continuous therapeutic ultrasound in myofascial pain syndrome: a randomized controlled study. Am J Phys Med Rehabil, 2015;94(7):547-54.

[21] Ragan BG. The Physiology and psychology of pain. In: Starkey C, editor. Therapeutic modalities. 4th ed. Philadelphia, PA: FA Davis; 2013. p. 32-51.

[22] Bingel U, Schoell E, Herken W, Buchel C, May A. Habituation to painful stimulation involves the antinociceptive system. Pain, 2007;131(1):21-30.

[23] Riedl V, Valet M, Woller A, Sorg C, Vogel D, Sprenger T, Boecker H, Wohlschlager AM, Tolle TR. Repeated pain induces adaptations of intrinsic brain activity to reflect past and predict future pain. Neuroimage, 2011;57(1):206-13.

[24] Watkins LR, Mayer DJ. Organization of endogenous opiate and non-opiate pain control systems. Science, 1982;216:1185-92.

[25] Morishita K, Karasuno H, Yokoi Y, Morozumi K, Ogihara H, Ito T, Fujiwara T, Fujimoto T, Abe K. Effects of therapeutic ultrasound on intramuscular blood circulation and oxygen dynamics. J Jpn Phys Ther Assoc, 2014;17(1):1-7.

[26] Ay S, Dogan SK, Evcik D, Baser OC. Comparison the efficacy of phonophoresis and ultrasound therapy in myofascial pain syndrome. Rheumatol Int, 2011;31:1203-8.