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Effects of high-power pain threshold ultrasound technique in patients with knee osteoarthritis: A single-blind randomized controlled trial

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ABSTRACT

Osteoarthritis (OA) is a highly prevalent, degenerative disease of the joints manifested by joint pain, tenderness, decreased function, and limited range of motion (ROM). The current study aimed at evaluating the therapeutic effect of the high-power pain-threshold ultrasound technique (HPPTUS) in comparison with conventional ultrasound (US) techniques in patients with knee osteoarthritis (KOA). A single-masked, pre–post randomized controlled trial was conducted. Fifty participants of both sexes (between 40 and 50 years of age), diagnosed with stage II knee osteoarthritis, participated in this study. They were randomized into two groups: Group A (experimental group, n=25), which received HPPTUS on the knee joint in addition to the traditional treatment (hot packs and isometric exercise for quadriceps), and Group B (control group, n=25), which received conventional ultrasound on knee joint in addition to the traditional treatment (hot packs and isometric exercise for quadriceps). Both groups underwent a four-week treatment plan in which sessions were conducted twice per week. The visual analogue scale (VAS) was used to estimate the intensity of pain, Digital Electronic Pressure Algometer was used to measure pressure pain threshold (PPT) on trigger point around knee, and Digital goniometer was utilized to assess ROM of the knee joint before and after treatment. The MANOVA test revealed statistically significant improvements in all variables (VAS, PPT, knee ROM) post-treatment compared to pre-treatment values in the HPPTUS group (experimental group) ($p < 0.05$), while the control group revealed statistically significant improvement only in VAS post-treatment compared with pre-treatment ($p < 0.05$). Comparison

between groups revealed statistically significant improvements in VAS, PPT, knee ROM in participants receiving HPPTUS compared with the control group ($p < 0.05$). High-power ultrasound can be effectively implemented in the treatment of knee OA as it produces significant improvements in the intensity of pain, pressure-pain threshold, and knee joint ROM.

KEYWORDS

Knee Osteoarthritis; High-Power Pain Threshold Ultrasound; Conventional Ultrasound

1. INTRODUCTION

Knee osteoarthritis (KOA) is a common form of osteoarthritis (OA). It is considered the most prevalent among all types of osteoarthritis, with an estimated prevalence of 12% to 35% in the general population (Pop et al., 2007; Quintana et al., 2008). It can be considered a musculoskeletal disabling disease which causes a significant effect on individuals and the society (Smith et al., 2019). Osteoarthritis is an over-the-globe problem that affects quality of life (QOL) and leads to a significant impact on the economy (Ackerman et al., 2005; Kotlarz et al., 2009). The most common symptoms of KOA include pain in the affected joint at rest, morning stiffness that lasts for less than half an hour, enlarged joint line with limited physical function, deformities and tenderness upon palpation. All these symptoms interfere with and reduce QoL (Kellegren & Lawrence, 1957; Johnson & Hunter, 2014).

The resulting socioeconomic burden in developed countries is approximately 1-2.5% of the gross domestic product. Due to the wide implication of KOA there is a need to develop new approaches to prevent or retard the progression of KOA (Chu et al., 2012; Edmonds, 2009; Nicholson et al., 2009)

Several investigations have indicated a conflict between patients' complaints of pain and their radiography results (Kornaat et al., 2006). A reasonable explanation is that pain can originate from myofascial trigger points (MTrPs) in the muscles surrounding the affected joint. (i.e., myofascial pain which cannot be observed in radiology). The term “myofascial pain” is described as “a complex of autonomic, motor, and sensory symptoms as a result of MTrPs” (Simons et al., 1999). MTrPs, which are hyperirritable regions found in muscles, are linked to palpable nodules often found in a taut band and are hypersensitive and painful upon palpation. Previous research has identified an increased incidence of myofascial pain in KOA patients (Alburquerque-García et al., 2015; Bajaj et al., 2001; Henry et al., 2012; Itoh et al., 2008). All OA patients presented with MTrPs, particularly found in

gastrocnemius muscle's medial head (92%) and the vastus medialis muscle (67%) (Henry et al., 2012).

Myofascial pain (MFP) and the presence of myofascial trigger points (MTrPs) are major contributors to joint pain and limitation associated with KOA. Moreover, treatment plans that focus on MTrPs effectively reduce pain and improve functionability in KOA patients (Dor & Leonid, 2017).

Ultrasound (US) is a common physical therapy modality used in treating patients with symptomatic knee osteoarthritis (Sangtong et al., 2019). Many clinical trials and basic researches revealed the effectiveness of US in alleviating the sufferings of the patients with KOA (Zhang et al., 2014; Kang et al., 2013; MacIntyre et al., 2013). Three systematic reviews studies confirmed the effectiveness of US in relieving pain and enhancing functionability, without any serious adverse effects (Loyola-Sánchez et al., 2010; Rutjes et al., 2010; Zeng et al., 2014).

Travell & Simons (1983) first introduced HPPTUS in 1983. This technique depends on increasing the power of ultrasound up to the patient's threshold pain level then reducing it to one half of that intensity and then increasing the power gain in a similar manner (Majlesi & Unalan, 2004; Unalan et al., 2011).

To our knowledge, no previous researches have reported implementing HPPTUS in treating KOA. Hereby, the objective of the current study is to evaluate the therapeutic effects of the HPPTUS technique and to compare its results with those of conventional US techniques. The study comparison was conducted by tracing pain intensity and functionability in individuals with symptomatic osteoarthritic knees.

2. METHODS

2.1. Study Design

A single-masked, pre–post randomized controlled trial was conducted according to the Helsinki Declaration (1964) and the guidelines of Consolidated Standards of Reporting Trials **(28)** This trial was performed at the physiotherapy clinic of the Modern University for Technology and Information, Faculty of Physical therapy from June 2021 to October 2021. The study protocol obtained initial approval of the Research Ethics Committee of Faculty of Physical Therapy (NO P.T.REC/012/002563) and it was registered at PAN African Clinical Trial Registration (PACTR) (registration number: PACTR201911702692851).

2.2. Participants

Fifty patients with knee osteoarthritis (18 males and 32 females), 40-50 years of age, were recruited from our orthopedic clinic, Cairo, Egypt. Each subject underwent an initial interview and a thorough evaluation by an orthopedist. Unilateral knee OA was diagnosed by both physical examination and X-ray images. Patients were assessed and included in the study based on the criteria developed by Kellgren & Lawrence class (II): pain around the knee, and limitation of ROM within the past 6 months (Kellgren & Lawrence, 1957). Patients who underwent assessment were excluded from participation in the study if they had: demonstrated any other types of arthritis, swelling around knee, use of oral or intra-articular corticosteroid (currently or within 6 months), physiotherapy treatment for KOA within 6 months prior to inclusion, uncontrolled hypertension, serious cardiovascular problems, history of NSAIDs or consumption of symptom-oriented slow-acting drugs for OA (e.g., hyaluronic acid or diacerein) a month prior to the assessment date. Ten subjects were excluded because they had been treated in the last month (Figure 1).

G-power 3.0.10 software (Heinrich Heine University Düsseldorf, Düsseldorf, Germany) was used to estimate the proper sample size for this study. The calculation was based on a previous pilot study conducted on 10 participants who received the same interventions. F-test repeated measurements, between factors α=0.05, β=0.2, and effect size=0.4 indicated that the appropriate number of participants for this study was 40 participants (20 participants per group). For the sake of accuracy, the number of each group participants was increased to 25 patients to compensate for possible drop outs.

2.3. Randomization, Concealment and Blindness

Patients were randomly assigned into two groups by a researcher who did not take part in neither the evaluation nor the treatment. Participants were recruited from orthopedic clinic from rail way hospital, Cairo, Egypt and assigned randomly by opaque sealed envelope into a group of the following: Group A (experimental): treated by HPPTUS in combination with hot packs and isometric exercise for quadriceps and Group B (control): received conventional US in combination with hot packs and isometric exercise for quadriceps. The treatment sessions were conducted twice/week for an overall duration of four weeks. Participants were only masked to the treatments at this trial (Figure 1).

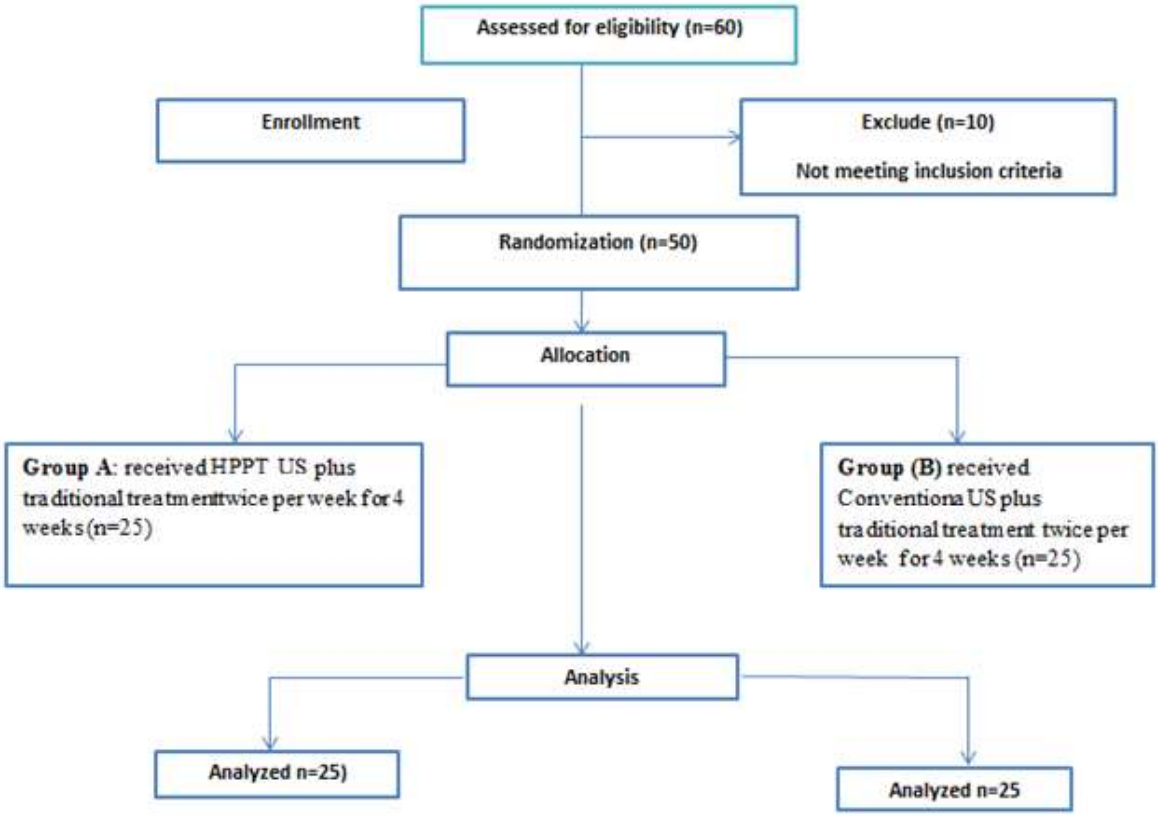

Figure 1. Consort Flow Chart for participants

2.4. Interventions

Both groups (experimental and control) received traditional treatment in form of hot packs placed around knee joint for 20 minutes and quadriceps isometric exercise. Patients were placed in the supine position and a towel was rolled-up and placed under the knee. After that, patients were given instructions to activate their thigh muscles as strong as maximally possible in an attempt to straighten the knee followed by 5 seconds of holding this maximum contraction, the exercise was performed in a set of 10 repetitions (Anwer & Alghadir, 2014).

- Experimental group (A):

Participants in this group were treated with HPPTUS in combination with the traditional treatment. The equipment used for US was Medserve (England NN114HE, Prosound / ULS-1000, S/N: U0547). It has a digital screen for time and intensity. It allows either pulsed or continuous mode, the head surface area is five cm^2. The position of subjects in this group was supine lying position with knee flexed 90 degrees and the therapist was standing beside the patient. Coupling agent (gel) was applied first over the skin to facilitate transmission of ultrasound energy, continuous mode, 1 MHZ, the US probe was fixed over the most painful point at knee joint. US intensity was

gradually raised until the patient reported unbearable pain. The US probe was held in a steady position for 3 seconds with the intensity at which unbearable pain was reported. Then, the intensity was decreased by half. After that, the US probe was moved in circles over the previously palpated trigger point for a duration of 15 seconds then US intensity was increased again same as previously stated. The maximum intensity varied between 1.5 and 2.5 W/ cm² **(**Unalan et al., 2011, Schulz et al., 2010; Anwer & Alghadir, 2014; Majlesi & Unalan, 2004). These steps were repeated three times. Then the session was terminated.

- Control group (B):

Patients in this group were treated with conventional US using the same device and the same position of the subject as in group A. Coupling agent (gel) was applied first over the skin to facilitate transmission of ultrasound energy, continuous mode, 1 MHZ, intensity 1.5 W/ cm² moving the head of US device in a circular motion over the most painful point at knee joint for 5 minutes, then the treatment was finished.

2.5. Outcome Measures

Assessment of participants was performed initially before commencing the treatment and was repeated 4 weeks just after implementation of the study. Outcome measures were: a) severity and intensity of pain which were indicated by VAS scores; b) Pressure Pain Threshold (PPT) measured by pressure algometer; c) knee ROM of both flexion and extension measured using digital goniometer. All variables were measured prior to and following treatment.

2.5.1. Pain severity

The visual analogue scale (VAS) is a valid and reliable tool to assess intensity of pain. In this tool, patients were instructed to identify the degree of pain on a scale from 0 to 10 while “0” indicates “no pain at all” and “10” indicates severe intolerable pain (Boonstra et al., 2008).

2.5.2. Pressure Pain Threshold (PPT)

Pressure Algometer is a valid, widely-used tool for assessment of PPT. The algometer used in this study was Algometer Type II, somedic AB, Sweden. Its tip was held perpendicular to the skin around the knee and a pressure of 30KPa/s was applied until patient reported discomfort with verbal affirmation. The value of the pressure at this point was noted down in kg/cm². The same procedure was repeated three times with 60-second intervals for each knee. The average pressure for each side was calculated and was accepted as the PPT (Fischer, 1998).

2.5.3. Knee range of motion

Digital goniometer was used to measure knee range of motion with the patient lying comfortably in supine and the therapist standing beside the tested limb. The goniometer's fixed arm was held parallel to the femur bone and its movable arm parallel to the tibia and fibula. The lateral femoral epicondyle was considered the point to which the goniometer's fulcrum was aligned. After holding the goniometer in the proper position, the patient was instructed to bend his knee so the flexion ROM is measured after that the patient was instructed to straighten his knee so the range of extension was measured (Svensson, 2019).

2.6. Statistical Analysis

All data were subjected to the test of normality (Shapiro-wilk test) which revealed normal distribution of all data except for the sex and the affected side. Unpaired T-test was used to compare demographic data. Treatment effects and the interaction between time and treatment were detected using the mixed multivariate analysis of variance (MANOVA). In case of between-groups differences, the Bonferroni test was conducted to assess these differences. Differences in magnitude between groups were assessed using by partial eta square (η^2) and finally, differences in sex and the affected side between both groups were assessed using Chi square (X^2) test. All statistical analyses were performed using SPSS version 23 (IBM Corp, New York, USA). For all the statistical tests, a p-value of <0.05 was considered statistically significant.

3. RESULTS

The t-test showed no statistically significant difference between the two groups ($p > 0.05$). Similarly, the chi-square test found no statistically significant differences between groups in sex and affected side ($p > 0.05$) (Table 1).

MANOVA revealed statistically significant differences between groups as Wilks' Lambda (Λ) = 0.091, f=54.98, p=0.0001 and η^2=0.909. Also, statistically significant difference was found at time as Λ = 0.035, f= 153.28, p=0.0001 and η^2 = 0.965. Lastly, statistically significant group-time interaction was reported as Λ = 0.051, f = 102.27, p=0.0001 and η^2 =0.949 (Table 2).

Multiple pairwise comparisons revealed a statistically significant difference between pre- and post-treatment values in all variables in the HPPTUS group (experimental) ($p < 0.05$) while only VAS was improved in control group. There were no statistically significant differences between groups pre-treatment ($p > 0.05$), but there was a significant difference between groups post-treatment ($p < 0.05$) (Table 2).

Table 1. Initial comparisons of the subjects' data in both groups (control and experimental)

		Experimental group	Control group	t-value	p-value
		Mean ± SD	Mean ± SD		
Age (years)		45.4 ± 3.4	45.7 ± 2.99	-0.296	0.769*
BMI(kg/m^2)		26.87 ± 1.29	27.1 ± 1.16	-0.577	0.567*
				χ^2 value	p-value
Sex	**Males**	8 (32%)	10 (40%)	0.347	0.555*
	Females	17(68%)	15(60%)		
Affected side	**Right**	16 (64%)	14 (56%)	0.333	0.563*
	Left	9 (36%)	11 (44%)		

Note: SD (Standard deviation); p-value (level of statistical significance); BMI (body mass index); χ^2: (Chi-squared value)

Table 2. Comparisons within and between groups (pre- and post-treatment)

Variables	Experimental group	Control group	p-value	f-value	η^2
VAS	**Mean±SD**				
Pre-treatment	8.45±0.998	8.60±994	0.94 **	0.226	0.006
Post-treatment	2±0.794	8.050±0.998	0.001 *	449.40	0.922
p-value (within)	0.0001 *	0.028 *			
% of change	76%	52%			
MD	6.45	4.4			
95% CI	5.96 to 6.93	0.63 to 1.03			
PPT	**Mean ±SD**				
Pre-treatment	2.05±0.64	1.87±0.70	0.41 **	0.669	0.017
Post-treatment	4.87±0.82	2.20±0.49	0.0001 *	154.16	0.802
p-value	0.0001 *	0.065 **			
%of change	137.5%	17.6%			
MD	-2.85	-0.32			
95% CI	-3.17 to -2.47	-0.672 to 0.02			
Knee Flexion					
Pre-treatment	88.50±7.57	93.02±8.75	0.89 **	3.049	0.074
Post-treatment	107.23±13.61	94.37± 8.78	0.001 *	12.58	0.249
p-value (within-group)	0.0001 *	0.414* *			
% of change	21.16%	1.45%			
MD	-18.73	-1.35			
95% CI	-22.04 to -15.40	-4.67to -1.96			
Knee Extension					
Pre-treatment	-10.64±2.40	-9.50±2.81	0.17 **	1.88	0.047
Post-treatment	-3.80±1.27	-7.85±3.17	0.002 *	11.50	0.23
p-value	0.0001 *	0.065* *			
% of change	64.2%	17.3%			
MD	-6.83	-1.65			
95% CI	-8.59 to -5.07	-3.41 to 0.10			

*Note: ** (no significant difference); *(significant difference); p-value (level of significance); SD (standard deviation); PPT (pressure-pain threshold); VAS (visual analogue scale); CI (confidence interval); MD (mean difference); η^2 (Partial Eta Square)*

4. DISCUSSION

The current study's outcomes revealed statistically significant differences in pain intensity, PPT and knee flexion and knee extension between both groups following treatment (p = 0.001, 0.0001, 0.001 and 0.002 respectively). While within groups, statistically significant differences were found in pain intensity in experimental and controls groups (p = 0.0001 and 0.028 respectively). The percent of change in HPPTUS group was 76% while conventional US was 52%.

The changes in PPT, knee flexion and knee extension in HPPTUS subjects were statistically significant, as p values were 0.0001, 0.0001 and 0.0001 respectively, while in conventional US group, there were no statistically significant differences (p = 0.065, 0.414 and 0.065 respectively). The percent of change in HPPTUS group was 137.5%, 21.16% and 64.2%, while in conventional US group was 16.6 %, 1.45% and 17.3% respectively.

As we can see, HPPTUS was more effective in decreasing pain intensity, threshold and increasing knee joint range of motion than conventional US among patients with KOA.

By reviewing the literature, the current study findings were found to be in agreement with the study done by Cameron (2017), which concluded that HPPTUS technique resolve trigger points much faster than conventional US technique which will decrease the number of physical therapy treatment sessions and also found to be more cost effective.

In the same line to the concept of the current study, the results of Majlesi & Unalan (2004) were in agreement with the current study. In their study, they deemed HPPT US more effective than conventional US in treating myofascial pain syndrome in terms of VAS and neck active lateral bending ROM. As well as Koca et al. (2014) who compared the effects of conventional US treatment and HPPT US to trigger points and found that HPPTUS therapy was found more effective than standard US.

Also, Haran & Kumar (2013) conducted a study to investigate the extent to which MTrP in the upper trapezius fibers are affected by static HPPTUS combined with transverse friction massage (TFM) and stretching. This study involved 30 subjects who were allocated into two groups at random. Each group had 15 participants who received the following treatment techniques: Group A received a combination of Static HPPTUS + TFM + Static Stretch of the upper trapezius. Meanwhile, Group B received a combination of TFM + Upper Trapezius static stretching. Both groups received intervention twice a week for 4 weeks. The study found a substantial difference between both groups in terms of lowering trigger points, pain, and improved function.

Moreover, Elhafez et al. (2020) investigated the effect of different US intensities (HPPTUS versus conventional US) on pain and myoelectric activity of MTrPs in the upper trapezius. Participants were assessed prior to and after treatment by indicating the intensity of pain on VAS while myoelectric activity was assessed by surface electromyography (EMG). The study revealed that both US approaches were effective in treating active MTrPs. However, HPPTUS was deemed superior.

The findings of our study were concomitant with the results of Sadeghnia et al. (2021) who assessed the immediate effects of HPPTUS on active MTrPs in the upper fibers of trapezius. They measured VAS, PPT and ROM of lateral neck flexion. The outcomes revealed significant improvements in all measured parameters after HPPTUS application on trigger points ($p < 0.001$).

On the contrary, Kim et al. (2014) found no statistically significant difference in PPT, VAS and ROM between HPPTUS and conventional groups following the treatment of senior patients with latent MTrPs. Similarly, Esenyel et al. (2007) assessed the effects of HPPTUS versus conventional US in the treatment of trigger points and reported no significant difference in VAS scores between both modalities.

In the current study, we found that results are considered significant in all variables with greater improvement in the HPPTUS group. This may be because it increases the temperature of soft tissues temporarily to increase their extensibility (Cameron, 2017), increased blood flow will remove pain-causing mediators from the site of application (Esposito et al., 1984), increased capillary density in muscles (Watson, 2000), improved cellular energy consumption (Hogan et al., 1982), increased capillary formation in poorly-perfused tissues (Molina et al., 2000).

A limitation of our study is that the patients in this study were not followed up after treatment. Thus, we do not know how long the positive changes might last after the treatment ended.

5. CONCLUSIONS

In the current study, HPPUS was found to be superior to conventional US in the treatment of knee OA. The former significantly decreased pain intensity and pressure pain threshold and significantly increased knee joint ROM compared with conventional US. The authors recommend that future researchers further investigate treatment-related changes in different age groups and include a follow-up program in their study design.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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