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Research Article

Low-Energy Versus Middle-Energy Extracorporeal Shockwave Therapy for Treating Pes Anserine Bursitis

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ABSTRACT

Introduction: Pes anserine bursitis (PAB) is a painful status inside the knee that may interfere with functional activities. Extracorporeal shockwave therapy (ESWT) may treat this disorder.

Objective: Comparing the effects of low- versus middle-energy ESWT on pain and functional activity in patients with sub-acute PAB.

Materials and Methods The study was a single-blind randomized trial. Twenty-eight patients with sub-acute PAB were randomly divided into two groups and received either low or middle-energy ESWT for three weeks. The numeric pain rating scale (NPRS), short-form McGill pain questionnaire (SF-MPQ), timed up and go (TUG) test, and Western Ontario and McMaster universities index (WOMAC) were evaluated before and 2 and 3 weeks after the intervention.

Results: A significant improvement was observed for low-energy ESWT in terms of NPRS (P=0.001), SF-MPQ (P<0.001), WOMAC (P<0.001), and TUG (P<0.001) 3 weeks after the intervention. Also, a significant improvement was observed following middle-energy ESWT application on NPRS (P=0.003), SF-MPQ (P<0.001), WOMAC (P<0.001), and TUG (P<0.001) 3 weeks after the intervention. A similar trend was observed between study time points and for all variables in each group. The only exception was the TUG, which showed no improvement between 2 and 3 weeks after the intervention for each study group. A significant improvement was observed in the NPRS between the two groups after 2 weeks (P=0.001) and 3 weeks (P=0.006), both favoring the middle-energy ESWT application.

Conclusion: Low- and middle-energy ESWT can effectively improve pain, functional activity, and mobility in patients with PAB.

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Introduction

Pes anserine bursitis (PAB) is an inflammatory disorder of the bursa beneath the sartorius gracilis and semitendinosus insertion [1]. This area is located at the proximal medial region of the knee, two inches below the medial knee joint line between the pes anserinus tendons [2, 3]. Of the 509 magnetic resonance imaging (MRI) of symptomatic adult knees, 2.5% were suspected of having an internal abnormality, revealed evidence of PAB [1]. This disease is more common in middle-aged, overweight women with osteoarthritis due to the female knees' different angulation, which applies extra force to the region where pes anserinus enters [4, 5].

Patients with PAB probably have pain [6], muscle weakness, and a reduced range of motion. Tenderness is always there with or without swelling [7]. The initial cause of PAB is tight hamstring muscles [8]. The development of PAB is associated with overweight, pes planus, valgus knee deformity, degenerative joint diseases, sports activities [9-12], trauma, overuse, and medial knee osteoarthritis [13].

The primary method of care for PAB is physical therapy. Rest is the most crucial thing to lessen pain [1]. Corticosteroid injection therapy [14], non-steroidal anti-inflammatory drugs, and acetaminophen are used to reduce inflammation and relieve pain [1]. Cryotherapy is thought to reduce pain [15, 16]. It has been shown that ultrasound can effectively reduce the inflammatory process in anserine syndrome [17]. Kinesio taping can reduce swelling and inflammation [18]. Also, rehabilitation exercises are recommended, including stretching and strengthening the adductors and quadriceps [19]. Surgery is demanded if conservative treatment fails [19]. However, none of these interventions can decrease inflammation and pain, thus improving function in these patients.

Several musculoskeletal problems are treated by extracorporeal shockwave therapy (ESWT), a non-invasive treatment method used for even soft tissue wounds [20]. This therapy has shown promising results in treating various musculoskeletal conditions, such as trochanteritis, epicondylitis, tendinitis, plantar fasciitis, and jumper's knee [21, 22]. The ESWT includes two types: Focused SWT, penetrating deep into the tissue [23], and radial SWT with a more superficial effect [24]. Different results have been obtained when comparing the effects of focus and radial ESWT on musculoskeletal diseases. Also, similar differences were observed between the effects of low and middle energy of the ESWT [25]. Based on its energy levels, shock wave therapy can be categorized into 3 groups: Low energy (0.08 mJ/mm^2), middle energy (0.08–0.28 mJ/mm^2), and high energy (>0.28 mJ/mm^2) [26-28]. Compared to lowenergy ESWT, highenergy ESWT is more uncomfortable and frequently necessitates intravenous analgesics. Thus, it is commonly carried out in a hospital setting. On the other hand, a physical therapist typically performs lowenergy ESWT in an outpatient setting [29]. No consistency is observed in classifying energy flux density (EFD) since the literature assessment found various energy parameters identified in different research projects. Despite this discovery, physicians commonly use levels of energy between 0.001 and 0.4 mJ/mm^2. Nitric oxide, released in response to low and middle EFD, is advantageous due to its analgesic, angiogenic, and anti-inflammatory actions in medical settings [30]. Many musculoskeletal conditions were treated with the middle- and low-energy ESWT techniques. Calcaneal bursitis, trochanteric bursitis, and calcific tendonitis of the shoulder joint are also routinely treated with the middle energy ESWT regimen. While lateral epicondylitis, PAB, and plantar fasciitis are common conditions treated by lowenergy ESWT [31]. The exact mechanism of the ESWT is still debated; however, it shows anti-inflammatory effects through molecular mechanisms, such as changes in the concentration of nitric oxide and other internal mediators. No exact clear mechanism exists to explain the effects of the ESWT on the PAB. However, the application of the ESWT was reported as an effective modality to improve the level of pain on bursitis with a decrease in substance P [32]. The ESWT acts as a mechanical stimulation to promote healing by mechanotransduction [33]. According to reports, biological reactions include bone remodeling, angiogenesis, tissue regeneration, and wound healing [33-37]. By hyperstimulation analgesia, ESWT may also reduce pain [38, 39]. According to previous studies, mechanotransduction is the primary mechanism through which ESWT initiates angiogenic and tissue regeneration responses at the cellular and molecular levels, producing positive therapeutic effects in clinical scenarios [36, 40]. Four ESWT reaction phases have been proposed based on prior research [41]: Physicochemical, biological, chemical, and physical. In the physical phase, shockwaves produce a positive pressure that causes energy to be reflected, absorbed, refracted, and transferred to tissues and cells [23]. In addition, cavitation appears to promote the ionization of biological molecules and the permeability of cell membranes. The physical stimulus triggers biochemical responses in the second phase of the physicochemical phase. To activate cell signaling pathways, biomolecules, such as adenosine triphosphate, are released due to the ESWT [42]. Then, the chemical phase's shock waves affect how ion channels in the cell membrane work and cause calcium to be mobilized [43]. Last but not least, the biological phase is where the ESWT exerts its influence on angiogenesis, anti-inflammatory effect, and bone and soft tissue wound healing [36, 43]. This study was conducted to compare the effects of low- vs middleenergy ESWT on the pain and functional activity of patients with sub-acute PAB.

Materials and Methods

Study participants

Twenty-eight patients were diagnosed with sub-acute PAB by a specialist in rheumatology and divided randomly into two intervention groups (lowenergy ESWT and middleenergy ESWT). The inclusion criteria included men and women between 30 and 55 years old diagnosed with sub-acute PAB, with an educational level of at least a diploma, having knee pain ≥3 up to 7 based on numerical pain rating scale (NPRS) during walking, ability to ambulate at least 30 meters on a flat surface without a walking device, and also ability to perform physical exercises with minimal support. The exclusion criteria included patients who were absent for two or more continuous sessions, patients with an enormous increase in pain level, a severe decrease in function in the knee throughout the sessions, concomitant diseases affecting their knee like rheumatoid arthritis, recent surgery or injury to the knee, an injection of intra-articular corticosteroid in the last 6 months, a history of cancer, dementia, neurological deficiency, heart pacemaker, pregnancy, or uncontrolled cardiovascular disorders.

The technique of simple random sampling has been used to allocate the patients into one of two intervention groups (either the lowenergy ESWT or middleenergy ESWT). The type of intervention was written on a small piece of paper, totaling 28 numbers, and placed in a flask. Each patient could randomly choose his/her intervention group by picking up a small, sealed, randomly filled envelope describing the treatment group. All patients completed the intervention sessions and assessments. Therefore, no dropout was observed during intervention sessions.

Study procedure

This study was a randomized, single-blind clinical trial. Besides, the statistical analysis was conducted by a researcher who did not know the type of intervention for each group. The data were collected by assessing the characteristics of volunteers in a demographic questionnaire (age, gender, weight, height, and body mass index). Each patient was evaluated before the intervention, then 2 and 3 weeks after.

The pain intensity was measured using NPRS by asking patients to select a number between 0 and 10. Zero indicates no pain, while 10 denotes extreme discomfort, the greatest agony possible and as horrible as you can imagine [44]. The pain was also assessed by a short-form McGill pain questionnaire (SF-MPQ) comprising 15 items. Eleven of these items are sensory: Gnawing, heavy, tender, splitting, hot/burning, shooting, stabbing, cramping, and splitting. The remaining four are affective: Grueling, nauseating, terrifying, punitive, and harsh. They are graded on a severity scale from 0 to 3 (0=none, 1=mild, 2=moderate, or 3=severe) [45].

Western Ontario and McMaster universities (WOMAC) index was used to measure functional activity with 24 items and 3 subscales. Physical function subscale includes 17 items activities, such as using stairs, rising from sitting, standing, bending, walking, getting in and out of a car, shopping, putting on/taking off socks, rising from bed, lying in bed, getting in and out of the bath, sitting, getting on/off the toilet, heavy domestic duties, and light domestic duties. The pain subscale includes 5 items: Walking, using stairs, in bed, sitting or lying, and standing upright [46]. The test questions are graded from none (0) to extreme (4) on a scale of 0-4, with mild (1), moderate (2), and severe (3) in between. The results are adjusted to a 100-point scale, the maximum for each subscale being 20 for pain, 8 for stiffness, and 68 for physical function. The three subscale scores can be added to get a final score [47-49]. The WOMAC score indicates the severity of the pain, stiffness, and limitations in function.

Functional mobility was assessed using the timed up and go test (TUG). The patients were instructed as follows: When I say go, get up, go to the marker in front of you, rotate around when you reach there, go back to your seat, sit, and walk fast but carefully. The length of time the patient needed to finish the test was recorded. When the signal to start is given, the stopwatch starts and finishes when the client hits the chair [50].

Each patient was under treatment for three sessions, one session per week. The patient in the lowenergy ESWT group was under shockwaves application with characteristics of a focused probe, 1000 shocks/session, and an EFD of 0.08 mJ/mm^2 per shock. Meanwhile, the patient in the middleenergy ESWT group was under

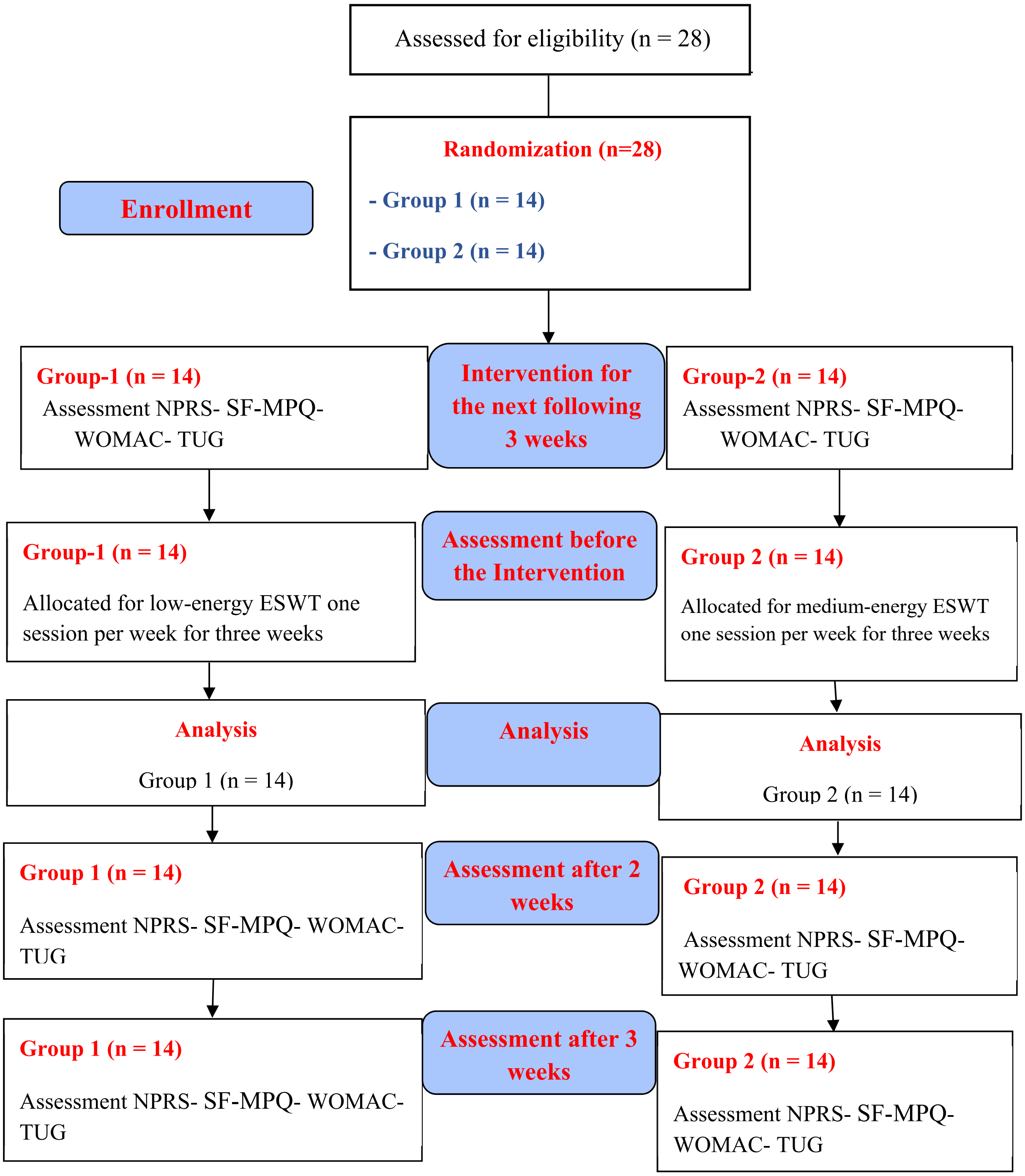

Figure 1. Flowchart of the study

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Abbreviations: WOMAC: Western Ontario and McMaster universities index; NPRS: Numeric pain rating scale; SF-MPQ: Short-form McGill pain questionnaire; TUG: Timed up and go; ESWT: Extracorporeal shockwave therapy.

shockwaves application with the characteristics of a focused probe, 2000 shocks/session, and an EFD of 0.16 mJ/mm^2 per shock. Both groups also received standard care, including 500 initial shocks as a warm-up, with similar characteristics, quadriceps strengthening isometric exercises, and a short period (7 minutes) of mild heating/infrared (Figures 1, 2, and 3).

The former researchers have mostly reported the ESWT as an effective modality in treating bursitis. These researchers studied the effects of this modality mostly in middle-energy ESWT and on different types and, characteristics and or stages of bursitis [51-53]. However, other researchers suggested low-energy ESWT to treat bursitis [54, 55]. No study compared the effects of low-energy versus middle-energy

Figure 2. Shockwave device

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ESWT in patients with the PAB. The rationale of this study was to identify which type of ESWT (low- versus middle-energy) can be more effective in treating patients with subacute stages of PAB. We also tried to identify a more effective window that should be applied for ESWT in treating patients with PAB. That was why we tried to distinctly clarify the low-energy versus middle-energy effectiveness on the patients suffering from PAB. Through this design, we can compare the efficacy of low- versus middle-energy ESWT application on pain, functional activity, mobility, and activity of daily living in patients with subacute PAB.

Statistical analysis

Statistical analysis was performed using SPSS software, version 24. The Kolmogorov-Smirnov test

Figure 3. Shockwave therapy for the PAB patient

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checked the normal distribution of data. The mean demographic data between the two groups were compared using separate independent sample t-tests. The means of the NPRS, SF-MPQ, WOMAC, and TUG before any intervention, 2, and 3 weeks after the treatment in each group were compared using a one-way analysis of variance (ANOVA) test for data with normal distribution and the Kruskal-Wallis test for data with non-normal distribution. Improvement in the mean scores of the NPRS, SF-MPQ, WOMAC, or TUG was compared between the two groups using an independent samples t-test for data with normal distribution and the Mann-Whitney U test for data with non-normal distribution.

Results

This study included 28 patients who were differentially diagnosed with PAB, including 19 women and 9 men. No discernible variances regarding demographic data were found between the 2 groups, according to the findings of the independent sample t-tests (Table 1).

Table 2 presents the descriptive statistics for the NPRS, SF-MPQ, WOMAC, and TUG.

The NPRS variable did not follow a normal distribution. The results of the Kruskal-Wallis test for the NPRS showed a significant improvement in each group separately, both in the low-energy ESWT (P=0.001) and middle-energy ESWT group (P=0.003).

The other variables did follow a normal distribution, and based on the ANOVA analysis, a significant improvement was observed regarding the SF-MPQ, WOMAC, and TUG for each group separately (Table 3).

The post hoc Bonferroni test results revealed a significant improvement in the NPRS for the low-energy ESWT group between baseline and 2 or 3 weeks after the intervention. Also, a significant improvement was observed between baseline and 2 or 3 weeks after the intervention. The middle-energy ESWT group revealed significant improvement in the NPRS between baseline and 2 weeks after and between 2 and 3 weeks after receiving the intervention, with a highly significant improvement between baseline and 3 weeks after treatment (Table 4).

Pain intensity was significantly improved based on the mean of SF-MPQ for both groups of lowenergy and middleenergy ESWT between all evaluation time points (Table 5). Regarding the mean score of WOMAC, a significant improvement was identified in low-energy ESWT application between the intervals. A similar trend was also found following middle-energy application (Table 5). Also, a significant difference was observed for the TUG between the initial assessment and each time of evaluation within each intervention group (low-energy, middle-energy). However, the difference between the second and third evaluation times was insignificant in terms of the mean TUG within each intervention group (Table 5; Figures 4, 5, 6 and 7).

Comparing the NPRS values among two groups of study by the Mann-Whitney U test showed a significant difference between the groups both after 2 weeks (P=0.001) and after 3 weeks (P=0.006) of intervention both in favor of the middle-energy ESWT application. No significant difference was observed in the NPRS mean scores between 2 and 3 weeks after the treatment. The mean scores of all SF-MPQ, WOMAC, and TUG for both groups did not show any significant difference between the groups at various times of evaluation, as per the results of the independent sample t-test (Table 6).

Table 1. Demographic data of the included participants

Demographical Data	Mean±SD/No.		Sig.
	Low Energy (n=14)	Middle Energy (n=14)	
Age (y)	50.42±4.9	48.9±8.1	0.56
Female	9	10	0.70
Male	5	4	0.70
Mass (kg)	83.6±14.6	85.3±15.4	0.77
Height (cm)	164.2±10.7	161.4±9.0	0.45
BMI (kg/m^2)	31.4±7.3	32.9±6.0	0.58

BMI: Body mass index; ESWT: Extracorporeal shockwave therapy.

Table 2. Descriptive statistics for the studied groups

Intervention Groups	Outcome Measure	Mean±SD		
		Assessment Intervals		
		Before the Intervention	After 2 Weeks	After 3 Weeks
Low-energy ESWT (n=14)	NPRS	6.57±0.65	5.214±0.80	3.28±0.6
	SF-MPQ	25.50±5.7	15.93±4.0	10.5±3.2
	WOMAC	51.1±14.2	34.92±8.3	24.92±7.5
	TUG	14.50±2.19	12.03±1.6	10.33±1.1
Middle-energy ESWT (n=14)	NPRS	6.7±0.47	4.14±0.7	2.36±0.9
	SF-MPQ	28.0±3.94	17.36±3.4	9.79±3.7
	WOMAC	46.71±11.61	30.6±8.0	18.78±5.9
	TUG	13.62±2.44	10.9±1.8	9.39±1.8

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Abbreviations: WOMAC: Western Ontario and McMaster universities index; NPRS: Numeric pain rating scale; SF-MPQ: Short-form McGill pain questionnaire; TUG: Timed up and go; ESWT: Extracorporeal shockwave therapy.

Table 3. The results of analysis of variance for the SF-MPQ, WOMAC, and TUG for each group

Intervention Groups	Outcome Measures	df	F	Sig.
Low-energy ESWT	SF-MPQ	41	41.443	0.001
	WOMAC	41	22.434	0.001
	TUG	41	22.198	0.001
Medium-energy ESWT	SF-MPQ	41	87.313	0.001
	WOMAC	41	35.277	0.001
	TUG	41	15.274	0.001

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Abbreviations: WOMAC: Western Ontario and McMaster universities index; SF-MPQ: Short-form McGill pain questionnaire; TUG: Timed up and go; ESWT: Extracorporeal shockwave therapy.

Table 4. Post hoc test results for the numeric pain rating scale for each group separately

ESWT Group	Assessment Interval	Sig.
Low energy	Before the intervention-after 2 weeks	0.001
	Before the intervention-after 3 weeks	0.001
	After 2 weeks-after 3 weeks	0.000
Middle energy	Before the intervention-after 2 weeks	0.032
	Before the intervention-after 3 weeks	0.003
	After 2 weeks-after 3 weeks	0.023

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ESWT: Extracorporeal shockwave therapy.

Table 5. Post hoc test results for the SF-MPQ, WOMAC, and TUG for each group and occasion separately

ESWT Group	Assessment Interval (i) Group	Assessment Interval (j) Group	Sig.		
			SF-MPQ	WOMAC	TUG
Low energy	Before the intervention	After 2 weeks	0.000	0.001	0.001
		After 3 weeks	0.000	0.000	0.000
	After 2 weeks	Before the intervention	0.000	0.001	0.001
		After 3 weeks	0.007	0.046	0.030
	After 3 weeks	Before the intervention	0.000	0.000	0.000
		After 2 weeks	0.007	0.046	0.030
Middle energy	Before the intervention	After 2 weeks	0.000	0.000	0.004
		After 3 weeks	0.000	0.000	0.000
	After 2 weeks	Before the intervention	0.000	0.000	0.004
		After 3 weeks	0.000	0.003	0.167
	After 3 weeks	Before the intervention	0.000	0.000	0.000
		After 2 weeks	0.000	0.003	0.167

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Abbreviations: SF-MPQ: Short-form McGill pain questionnaire; TUG: Timed up and go; WOMAC: Western Ontario and Mc-Master universities index; ESWT: Extracorporeal shockwave therapy.

Table 6. Comparing the mean differences of the NPRS, SF-MPQ, WOMAC index, and TUG between low- and medium-energy ESWT application

Outcome Measure	Assessment Interval	Mean±SD		Sig.
		Low Energy	Middle Energy	
NPRS	After 2 weeks	1.35±0.5	2.57±0.6	0.001
	After 3 weeks	3.28±0.6	4.35±1.1	0.006
	Between 2 and 3 weeks	1.92±0.7	1.78±0.9	0.847
SF-MPQ	After 2 weeks	9.57±4.9	10.64±3.4	0.506
	After 3 weeks	15.0±4.4	18.21±5.9	0.116
	Between 2 and 3 weeks	5.42±2.6	7.57±4.1	0.110
WOMAC	After 2 weeks	16.21±8.6	16.14±5.8	0.980
	After 3 weeks	26.21±9.8	27.92±8.0	0.610
	Between 2 and 3 weeks	10±4.9	11.78±4.2	0.313
TUG	After 2 weeks	2.46±1.1	2.69±1.3	0.625
	After 3 weeks	4.17±1.6	4.22±1.9	0.944
	Between 2 and 3 weeks	1.70±0.8	1.52±0.9	0.595

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Abbreviations: SF-MPQ: Short-form McGill pain questionnaire; TUG: Timed up and go; WOMAC: Western Ontario and Mc-Master universities index; ESWT: Extracorporeal shockwave therapy.

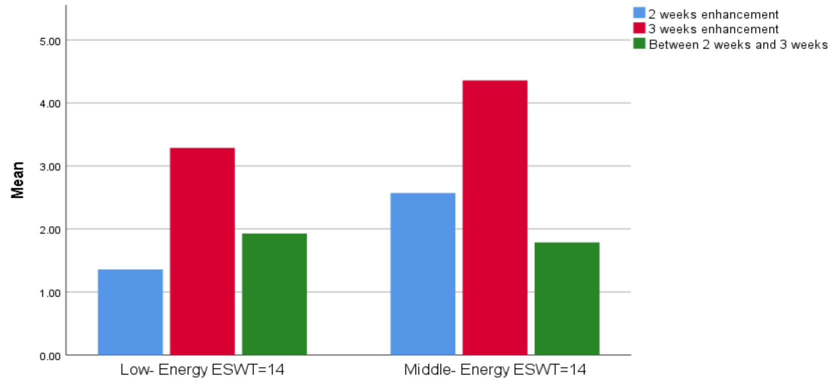

Figure 4. The mean improvement for the numeric pain rating scale values

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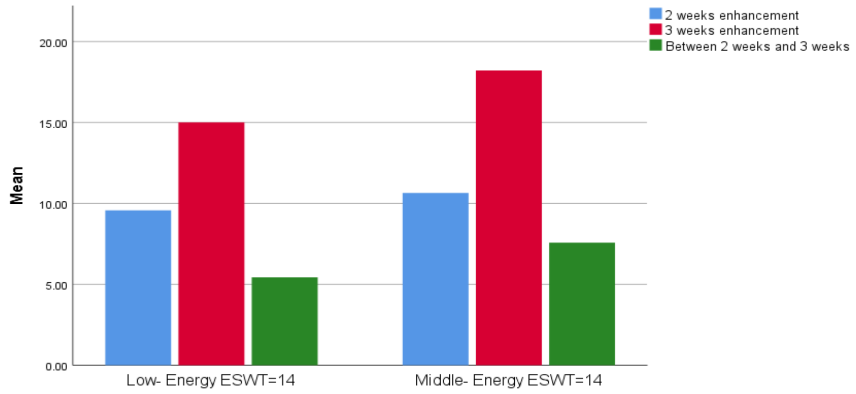

Figure 5. The mean improvement for the short-form McGill pain questionnaire

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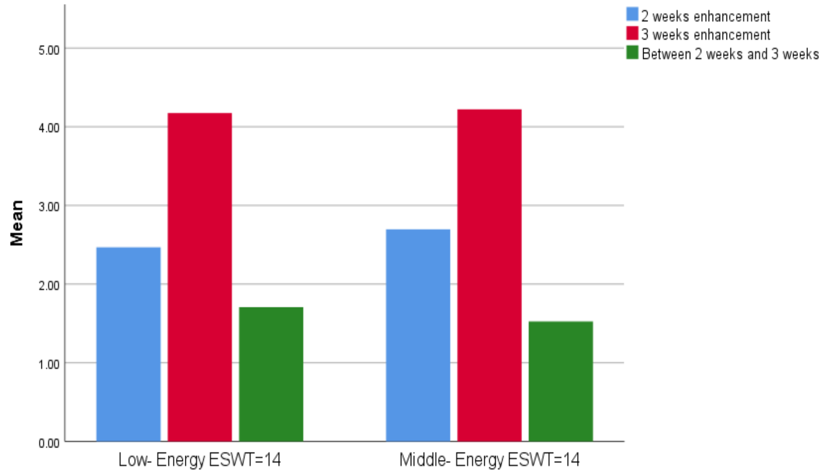

Figure 6. The mean improvement for the Western Ontario and McMaster universities index

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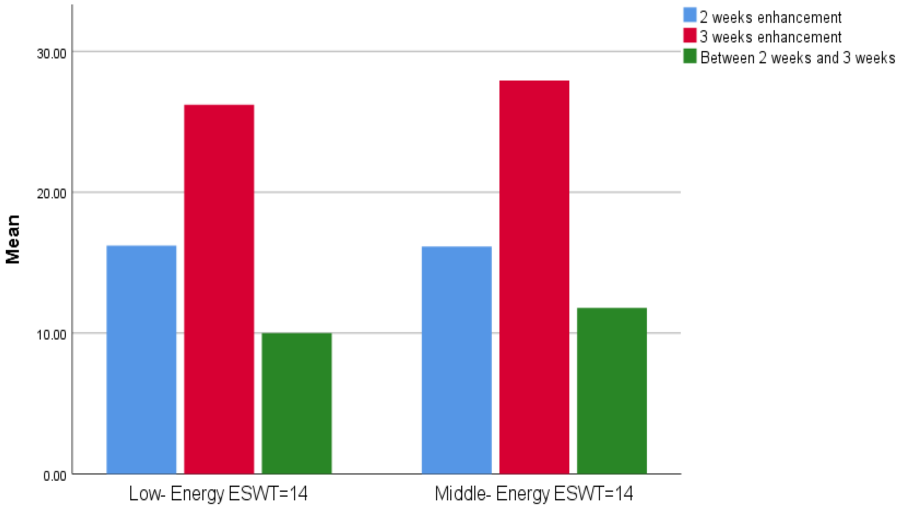

Figure 7. The mean improvement for the timed up and go test

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Discussion

This study was conducted to compare the effects of two ESWT intervention protocols (lowenergy versus middle-energy ESWT) on pain, functional activity, and functional mobility in patients with PAB. They were equally effective in improving SF-MPQ, WOMAC, and TUG scores, but middleenergy ESWT was more effective in improving the NPRS score compared to lowenergy ESWT. No previously identified study was conducted to compare the effect of lowenergy versus middleenergy ESWT in patients with sub-acute PAB. Based on the literature review, this may be the first study documenting the impact of applying ESWT on pain level, functional activity, and functional mobility in patients with PAB.

In the current study, and to the best of our knowledge, no other research has assessed the effect of ESWT on the NPRS in patients with PAB. Compared to other studies that used ESWT in different types of bursitis, Vitali et al. studied the impact of ESWT on pain level and hip range of motion following trochanteric bursitis, as measured by the NRPS. The results of this study are consistent with our results. Four months into therapy, they discovered a considerable reduction in pain [52]. Acar et al. assessed the pain level and compared the effects of lowenergy versus middleenergy ESWT in treating snapping scapula bursitis. The pain intensity demonstrated a higher significant improvement in the middleenergy group compared to the lowenergy group [53]. The results are consistent with our result that the pain improved more after using middleenergy ESWT. They conducted another study assessing the effect of ESWT in patients with scapulothoracic bursitis. The researchers compared the results to a group that received a corticosteroid injection in the area and reported a lower average pain level [53]. The result of this study was consistent with our results in terms of pain improvement after using ESWT, three sessions per week. Maffulli et al. studied the effects of ESWT in patients with trochanteric bursitis in both short- and long-term periods. The pain level was significantly reduced [51]. The result was consistent with our results regarding pain relief. Chahar and Sharma investigated the efficacy of ESWT in combination with contrast bath and static Achilles tendon stretch in people suffering from retrocalcaneal bursitis. The patients' pain was reduced and got better [54]. The result was consistent with our results in terms of pain improvement.

Vitali et al. used the MPQ to assess patients with trochanteric bursitis. The results were consistent with the results of our study, showing a significant improvement in pain level [52]. Another study by Khosrawi et al. used the SF-MPQ in patients with PAB, and their results were consistent with ours. The pain relief was significantly lower after the intervention in this study, based on the SF-MPQ [55]. The decrease in pain level may have been due to the pain gate control theory. Shock waves may have hyper-stimulated nerve receptors, causing them to send high-intensity impulses that limit pain signals. Also, shock waves may have caused free radicals to form near nerve endings, altering the chemical environment and reducing the intensity of pain impulses [56]. Shock waves may have also reduced muscle tone by enhancing the tissue's elasticity and energy. It may have also improved blood flow and the distribution of P substance, which is responsible for pain perception in a particular area [57].

Acar et al. used another outcome measure, the Constant-Murley scoring, to assess functional activity. The results were consistent with our study, which showed that the middleenergy ESWT demonstrated higher scores than the group receiving lowenergy ESWT [53]. Maffulli et al. used the lower extremity functional scale to assess functional activity after using ESWT but found no significant differences in functional ability [51]. The result is inconsistent with ours, which showed that the functional activity improved following the ESWT application. Chahar and Sharma showed that functional activity improved after using ESWT for patients with retrocalcaneal bursitis, measured by the Roles and Maudsley's score [54]. The result is consistent with our study. The improvement in functional activity may be because shockwave therapy may have reduced pain and inflammation, allowing the patient to engage in physical activity more comfortably and with lower limitations. Additionally, shockwaves can promote tissue regeneration and healing by increasing blood flow and promoting the growth of new blood vessels in the affected area. This therapy can help patients recover more quickly from injuries and improve their physical function. Furthermore, shockwaves may also have a beneficial effect on muscle strength and flexibility and can increase the production of growth factors, which can help improve muscle strength and flexibility [58, 59].

So far, this study is the first to demonstrate the use of TUG in patients with PAB, and no study has used other outcome measures to assess functional mobility in patients with bursitis. A highly significant difference was observed for each group (Table 3). The post hoc test results revealed an essential difference between the intervals in the TUG test within each group (low-energy, middle-energy) separately. However, no significant difference was observed in this outcome measure between the 2 and 3 weeks after the intervention (Table 5). The between-group comparison result revealed no significant differences in the mean score of the TUG test after 2 and 3 weeks of treatment and between 2 and 3 weeks of intervention (Table 6). After undergoing ESWT, patients' functional mobility appears to have improved through various processes. The analgesic effect, improved perfusion in ischemic regions, activation of growth factors (comprised of vascular endothelial growth factor, proliferative cell nuclear antigen, nitric oxide from endothelial cell synthase, and bone morphogenetic protein 2), and the process of healing, as well as a reduction in inflammation, can all be the contributing factors to ESWT [60].

Both low-energy and middle-energy ESWT are effective and can be applied in the physical therapy clinic to reduce pain and improve functional activity and mobility in patients with PAB. However, middleenergy ESWT is recommended for patients with higher pain intensity. For the sub-acute stage of PAB, in which pain may prevent patients from participating in physical activity, middle-energy ESWT may be more helpful in decreasing pain and allowing patients to be more active and mobile.

Conclusion

Low-energy and middle-energy ESWT methods may be effective in treating patients with PAB. However, the group that received the middle energy ESWT may have greater improvement in pain, functional activity, and mobility. Therefore, for the sub-acute stage of PAB, in which pain may prevent patients from participating in physical activity, middleenergy ESWT may be more helpful in decreasing pain and allowing patients to be more active and mobile.

The COVID-19 pandemic was a limitation of our study since the pandemic affected patient participation. We recruited patients with the sub-acute stage of PAB. Still, we faced limitations in finding eligible patients, primarily due to their fear of being in a health center to follow their treatment. Besides, long-term follow-up was impossible for most patients. Long-term implications of such treatment methods are necessary to manage PAB and should be investigated.

We suggest additional research to investigate the long-term effects of lowenergy and middleenergy ESWT. This goal requires examining the impact of low energy and middleenergy ESWT on other stages of the PAB and the different types of bursitis, with additional outcome measures and having placebo or control groups.

Ethical Considerations

Compliance with ethical guidelines

All study procedures followed the guidelines of the Scientific Board and Ethics Committee of Tehran University of Medical Science. The researcher received ethical approval from the Ethics Committee of the School of Nursing and Midwifery and Rehabilitation, Tehran University of Medical Sciences (Code: IR.TUMS.FNM.REC.1401.125). The participants were asked to read and sign the written consent form. The patients were also informed about the purpose and practical stages of the study before any intervention. The trial has also been approved by the Iranian Registry of Clinical Trials (IRCT) (Code: IRCT.20221228056970N1).

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Authors' contributions

Conceptualization, study design, and critical revision of the manuscript for important intellectual content: Siamak Bashardoust Tajali and Kazem Malmir; Supervision: Siamak Bashardoust Tajali; Data acquisition: Raghad Talib Taha Khazraji; Data analysis, data interpretation, and drafting of the manuscript: All authors.

Conflict of interest

The authors declared no conflict of interest.

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