J. Phys. Ther. Sci. 37: 209–214, 2025

The Journal of Physical Therapy Science

Original Article

Effect of extension on stiffness of the teres minor muscle following extracorporeal shock wave therapy for frozen shoulder: a double-blind, randomized, controlled trial

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Abstract. [Purpose] The mechanism of action and the position and site of Radial pressure wave therapy are unclear. This study aimed to evaluate the effect of shoulder position on muscle stiffness after radial pressure wave therapy. [Participants and Methods] This randomized, double-blind, parallel-group controlled trial included 32 orthopedic clinic participants. Using the block replacement method, patients were randomly assigned to a stretching group (IR group) or a shortening group (0 group) in a 1:1 ratio. Muscle stiffness was measured using ultrasonography (GE LOGIQ S8) with a 9 MHz linear transducer in B mode. Measurements were performed along the long axes of the teres minor, infraspinatus, and deltoid muscles. Radial pressure wave therapy were applied only to the teres minor (3.0 bar, 12 Hz, 2,000 shots). Muscle stiffness testers were blinded to the upper limb position during Radial pressure wave therapy. [Results] Teres minor muscle stiffness was significantly decreased within and between groups, and the deltoid muscle stiffness was significantly decreased within groups in the IR group. [Conclusion] Radial pressure wave therapy applied with the muscle extended reduced muscle stiffness more than Radial pressure wave therapy applied in the shortening position.

Key words: Radial pressure wave, Frozen shoulder, Ultrasonography

(This article was submitted Jan. 5, 2025, and was accepted Feb. 10, 2025)

INTRODUCTION

Frozen shoulder is a disease that causes progressively more pain and gradual narrowing of the joint range of motion[1)]. Prevalence is 2–5%, and it is more common in women than in men in their 40s–60s[2)]. Treatment methods for frozen shoulder include patient education, glucocorticoid medication, intra-articular injections, physical therapy, and exercise therapy[2, 3)]. Physical therapy is the first choice among conservative therapies because of its effectiveness in improving the limited range of motion and reducing pain[4)]. However, few studies have reported the outcomes of conservative treatment for muscle contractures in frozen shoulder. Therefore, there is a need to establish an effective conservative treatment for muscle contractures in frozen shoulder. Previous studies have reported the treatment effects of the radial pressure wave (RPW), especially in osteoarticular disorders and tendons. RPW has also been reported to reduce muscular pain and decrease muscle stiffness[5)]. Lee reported an increased range of motion in shoulder flexion and external rotation and decreased pain after extracorporeal

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shock wave therapy for adhesive capsulitis of the shoulder[6]. Zhang et al. concluded that extracorporeal shock wave therapy for frozen shoulders was effective for range of motion and pain reduction[7]. Chen et al. reported improved OSS and CSS scores after extracorporeal shock wave therapy for adhesive capsulitis of the shoulder[8]. All of these studies reported increased range of motion, pain reduction, and functional improvement, but they did not clearly describe the limb position or target areas to be treated with the RPW nor the effect on muscle stiffness. Increased blood flow has been reported as an effect of RPW[9, 10]. In addition, it has been reported that after muscle stretch, intramuscular vasodilation increases muscle blood flow[11]. Increased blood flow within muscles decreases muscle stiffness[12]. We hypothesized that delivering RPW to stretched muscles would decrease muscle stiffness more than delivering RPW to shortened muscles. Therefore, RPW in stretched muscles may decrease muscle stiffness. This study aimed to determine the effect of different shoulder positions on muscle stiffness during the RPW of frozen shoulder muscles.

PARTICIPANTS AND METHODS

The study was conducted in accordance with the principles of the Declaration of Helsinki. It was approved by the Ethics Committee of our institution (approval number: 2021-125) and registered with the University Hospital Medical Information Network (UMIN000047262, 3/23/2022). The conduct and reporting of this study adhered to CONSORT guidelines[13]. This was a randomized, double-blind, parallel-group, controlled trial (Fig. 1). The participants were 32 patients who presented at an orthopedic clinic. The participants were diagnosed with rotator cuff tears, shoulder periarthritis, or adhesive shoulder arthritis. Participant recruitment began in April 2022, and data collection was completed in March 2023. The sample size for this study was determined using G power 3.1, which indicated that 15 patients were required in each group (effect size, 0.4; power, 0.8).

The inclusion criterion was a shoulder 90-degree flexion and internal rotation of 0 °or less and a shoulder flexion range of motion of 90 degrees or greater. Patients who could not undergo RPW due to pain were excluded. The purpose of the study was explained verbally to the participants, and their consent was obtained.

Patients were randomly assigned in a 1:1 ratio to the two groups using the replacement block method. Group 0 was defined as the group exposed to RPW at 0° of shoulder flexion. The IR group was exposed to RPW in the 90-degree shoulder flexion position with maximum internal rotation. An independent researcher who was not involved in the treatment or outcome measurements implemented the randomization. All the participants and assessors were unaware of the group assignments.

Muscle stiffness was measured using ultrasonography (GE, LOGIQ S8, Tokyo, Japan) with a 9 MHz linear transducer in B-mode. Measurements were taken along the long axis of the teres minor, infraspinatus, and deltoid muscles (Fig. 2).

The transducer was placed posterior to the axilla, and the teres minor and infraspinatus were viewed from a short-axis angle. The transducer was then switched to the long-axis operation. The deltoid is depicted in the superficial layer of the long-axis image of the teres minor.

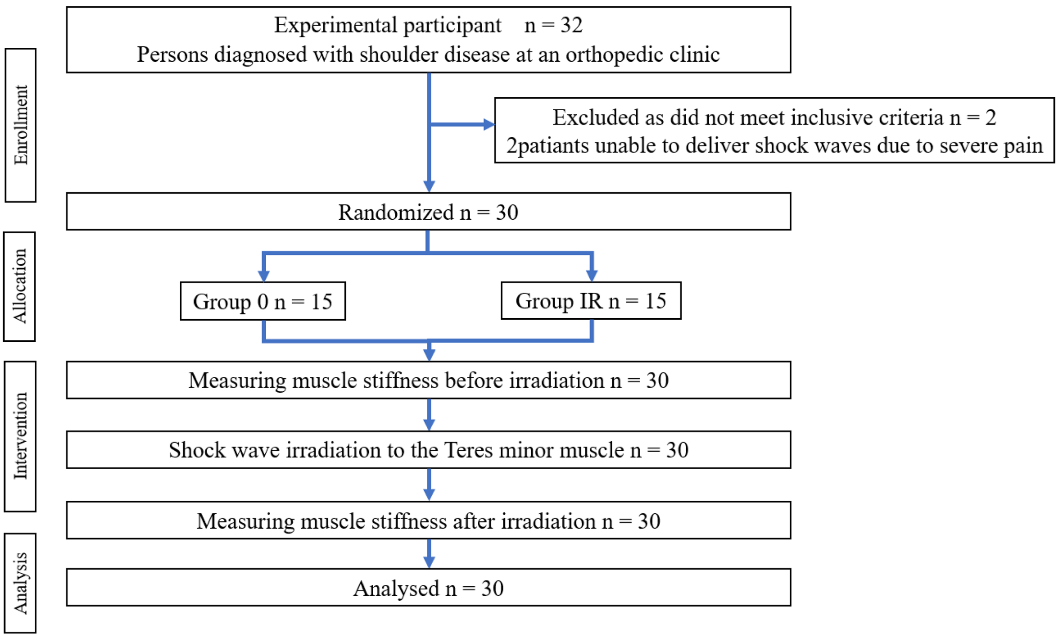

Fig. 1. Participants flow diagram.
Group IR: group internal rotation.

All muscle stiffness measurements were performed in the supine position with the shoulder joint in 90-degree flexion. Subsequently, the setting of the ultrasonography was changed to the shear wave elastography mode, and the shear wave velocity (m/s) was measured. Three regions of interest were randomly selected for each muscle, and the average was used as the representative value. RPW was delivered only to teres minor (3.0 bar, 12 Hz, 2,000 shots). RPW from STORZ MEDICAL was used in this study. Group 0 was placed in the supine position with 0° shoulder flexion (Fig. 3). Group IR was positioned at maximum internal rotation in addition to 90° shoulder flexion (Fig. 3). The stiffness of the three muscles was measured after RPW. One physical therapist administered all RPW treatments. During irradiation, the muscle stiffness testers waited in a separate room and were blinded to the position of the RPW. The intra-rater reliability of this analysis method was examined in advance. One examiner measured the muscle stiffness of 10 healthy adult participants twice at an interval of 1 h according to the above method. The intra-rater reliability was defined as poor (<0.5), moderate (0.5–0.75), good (0.75–0.9), and excellent (>0.9). As measures of absolute reliability, the standard error of measurement (SEM) and MDC95 were calculated[14].

Comparisons of the changes in muscle stiffness before and after RPW and between groups were performed using a two-way analysis of variance. Statistical significance was set at $p<0.05$. Statistical analyses were performed using IBM SPSS statistics version 27.

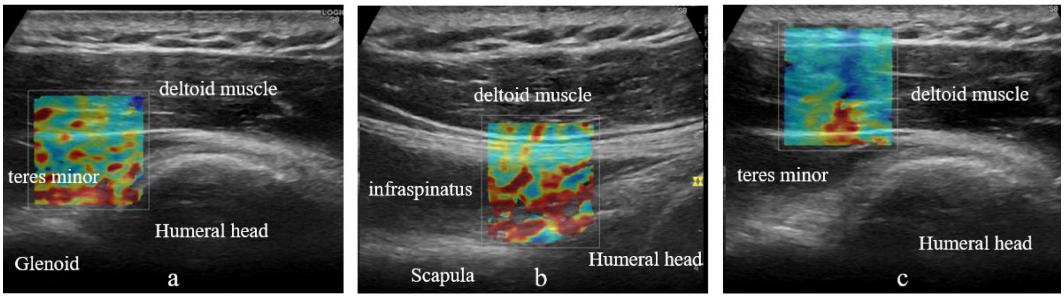

Fig. 2. Ultrasound image of teres minor, infraspinatus muscle, and deltoid muscle.
a: teres minor, b: infraspinatus, c: deltoid muscle.

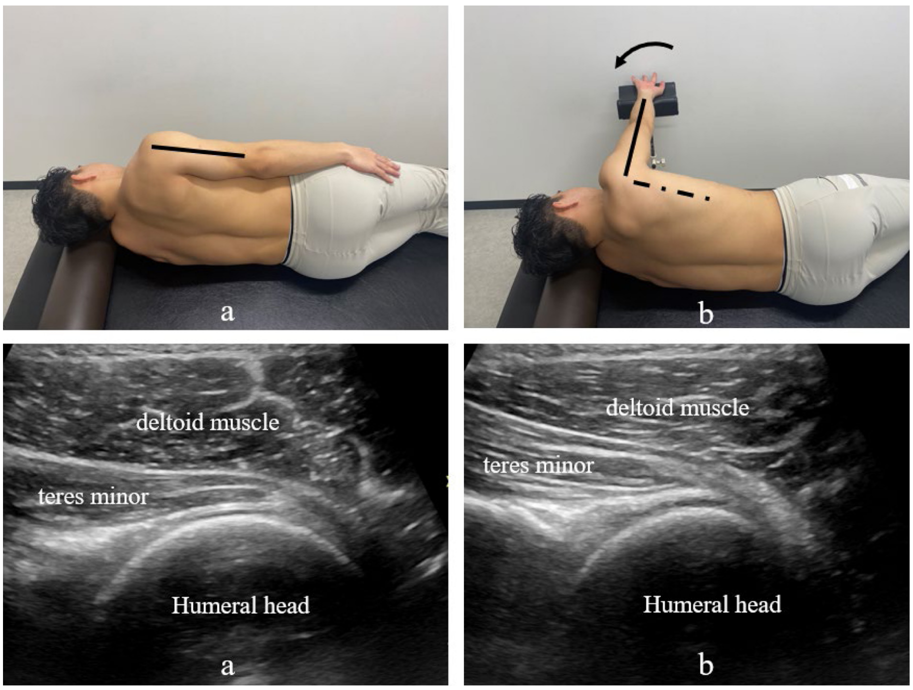

Fig. 3. Limb position when delivering the radial pressure wave (RPW), and the ultrasound image of the area to be irradiated RPW for each limb position.
a: group 0 (shortening group): 0 degrees of shoulder flexion.
b: group IR (group internal rotation) (stretching group): 90 degrees of shoulder flexion with maximum internal rotation.

RESULTS

Ten healthy adults (age 21.5 ± 2.3 years, height 176.6 ± 7.3 cm, weight 71.3 ± 9.3 kg) were included. The intra-assessor reliability intraclass correlation coefficient (ICC) (1.1) for muscle stiffness was 0.96 for the teres minor, 0.98 for the infraspinatus, and 0.83 for the deltoid muscle, respectively. Intra-assessor reliability was excellent for the teres minor and infraspinatus muscles and good for the deltoid muscle. The MDC95 was 0.35 for the teres minor, 0.36 for the infraspinatus, and 1.87 for the deltoid muscle (Table 1).

Thirty participants met the inclusion criteria and were included in the study. Two participants were excluded because of pain during the RPW. There were no significant differences in age (p=0.63), weight (p=0.68), or height (p=0.61) between the two groups (Table 2). Table 3 shows the changes in muscle stiffness before and after RPW and between the groups for each muscle. The changes in the muscle stiffness of the teres minor are shown below. There was a main effect of RPW on muscle stiffness changes in the teres minor before and after treatment within the group (p<0.01). There was also a significant difference between the IR and Group 0 (p<0.05). An interaction was also observed before and after RPW and between the groups (p<0.05). Changes in muscle stiffness in the infraspinatus are as follows: There was no main effect of the infraspinatus on muscle stiffness changes before and after RPW in the group (p=0.86). There was also no significant difference between the IR and 0 groups (p=0.52). There was also no interaction between pre- and post-RPW or between-group comparisons of muscle stiffness changes (p=0.99). The changes in deltoid muscle stiffness are shown below. There was a significant effect of RPW on deltoid muscle stiffness changes before and after treatment within the groups (p<0.05). There was no significant difference between the IR group and Group 0 (p=0.40). There was also no interaction between pre- and post-RPW or between-group comparisons of muscle stiffness changes (p=0.57).

DISCUSSION

The results of this study indicated that RPW delivered to the teres minor muscle in the stretched position significantly reduced the stiffness of the teres minor and deltoid muscles. In a systematic review, RPW for frozen shoulder was reported to increase the external rotation range of motion, reduce pain, and improve Constant–Murly Scores[7].

Table 1. Intra-rater reliability in the measurement of muscle stiffness (ICC1.2)

	ICC	95% CI	SEM	MDC95
Teres minor (n=10)	0.96	0.20–0.73	0.32	0.89
Infraspinatus (n=10)	0.98	0.08–0.29	0.13	0.36
Deltoid muscle (n=10)	0.83	0.43–1.39	0.67	1.87

ICC: intraclass correlation coefficient; MDC95: minimum detectable change at the 95% confidence level.

Table 2. Demographics of participant’s physical characteristics

	Group 0 (n=15)	Group IR (n=15)
Age (years)	59.8 ± 7.4	61.6 ± 12.7
Weight (kg)	64.3 ± 9.2	60.1 ± 10.1
Height (cm)	165.7 ± 9.2	163.7 ± 9.8
Sex, Male/Female (n)	7/8	7/8

Group IR: Group internal rotation.

Table 3. Comparison of muscle stiffness changes within and between groups

		Pre	Post
Tm	Group 0 (n=15)	3.4 ± 0.75 m/s	2.95 ± 0.9 m/s
	Group IR (n=15)	4.37 ± 0.58 m/s	2.77 ± 0.38 m/s*, **
ISP	Group 0 (n=15)	2.95 ± 0.57 m/s	2.93 ± 0.59 m/s
	Group IR (n=15)	3.07 ± 0.8 m/s	3.04 ± 0.72 m/s
Del	Group 0 (n=15)	2.77 ± 0.83 m/s	2.36 ± 0.65 m/s*
	Group IR (n=15)	3.04 ± 0.88 m/s	2.41 ± 0.53 m/s*

Significant difference compared to before the intervention. *p<0.05.
Significant difference compared to other groups. **p<0.01.
Tm: teres minor muscle; ISP: infraspinatus muscle; Del: deltoid muscle.

However, in previous studies on RPW in the shoulder, the target muscle was not described in detail, and the painful area was irradiated. In addition, the position of RPW delivery has not been clearly defined. Several previous studies on RPW delivered to muscles have been reported.

In a study where RPW was applied to the hamstrings to improve hamstring flexibility, the group that received both RPW and stretching reported better hamstring flexibility than the group that received stretching only. In addition, a previous study of RPW on the triceps muscle of stroke patients reported a decrease in triceps muscle tone after RPW was delivered[15].

These studies reported an improved range of motion of the hip or ankle after RPW delivery. However, the stiffness of the muscles was not measured; therefore, it is not clear what caused the improved range of motion. In addition, no previous studies have delivered RPW to frozen shoulder muscles or examined their stiffness. Patients with shoulder disease often present with shoulder internal rotation limitation due to tightness of the muscles and joint capsule in the posterior shoulder[16].

Therefore, in this study, RPW was delivered to the teres minor, a muscle that can cause range of motion limitations. This study focused on the shoulder position during RPW of the teres minor in frozen shoulder and its effect on muscle stiffness.

The results of this study showed that RPW delivered in the limb position in which the teres minor muscle was stretched resulted in a greater reduction in muscle stiffness. The RPW delivered through the deltoid muscle to the teres minor muscle resulted in a similar decrease in muscle stiffness in the deltoid muscle. Previous studies have reported increased blood flow in areas where RPW was delivered[9, 10]. Additionally, previous studies have reported that increased blood flow decreases muscle stiffness[12]. When a muscle is stretched, the blood vessels within the muscle are also stretched. As blood vessels within the muscle are stretched, the vessel diameter narrows, and the blood flow velocity increases. In other words, when delivering RPW, stretching the muscle rather than relaxing it may increase blood flow within the muscle.

In this study, we expected that the RPW to the teres minor muscle would have a spreading effect, causing a decrease in muscle stiffness in the nearby infraspinatus. However, no significant difference in muscle stiffness was observed in the infraspinatus after the RPW to the teres minor muscle.

In addition, because the deltoid muscle is located on the surface of the teres minor muscle, when the RPW is applied to the teres minor muscle, it is applied through the deltoid muscle. The deltoid muscle is supplied by the posterior brachial artery, which is the same blood vessel that supplies the teres minor muscle. Therefore, it is expected that the blood flow within the deltoid muscle will also increase when the RPW is applied to the teres minor muscle. In addition, because the deltoid muscle is located more superficially than the teres minor muscle, it is more easily affected by the RPW, and it is possible that the muscle stiffness decreased without being affected by the position of the upper limb.

The results of this study showed that the muscle stiffness of the deltoid muscle and the teres minor muscle decreased, and no significant changes were observed in the muscle stiffness of the infraspinatus.

In other words, the effect of RPW on the muscles is localized. Therefore, when delivering RPW to a muscle, it is necessary to identify the target muscle accurately.

This study has two limitations. Firstly, the mechanism underlying the observed decrease in muscle stiffness remains unclear. Previous studies have reported that increased blood flow decreases muscle stiffness[12]. However, this study did not measure the blood flow in the muscles before and after RPW. Therefore, the relationship between decreased muscle stiffness and blood flow remains unclear. Thus, future studies are necessary to evaluate the changes in muscle blood flow during RPW. Secondly, the long-term effects are unclear. Previous studies have reported that Multiple Routine RPWs to the muscle have lasting effects on blood flow increase[10]. This study examined the immediate effects of RPW. Therefore, long-term changes in muscle stiffness with periodic RPW need to be studied.

Conflict of interest

The authors declare no conflicts of interest.

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