

Research Paper



Effects of 8-Week Aquatic Training on Pain, Range of Motion, and Muscle Activity in Older Adults With Shoulder Impingement Syndrome: A Randomized Controlled Trial

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ABSTRACT

Purpose: Shoulder impingement syndrome (SIS) is the most prevalent issue among shoulder disorders. Given the promising outcomes of aquatic physiotherapy in rehabilitation, this study aimed to evaluate the impact of an 8-week aquatic training program on pain, range of motion (ROM), and electrical activity in the shoulder of older adults suffering from SIS.

Methods: A total of 30 male military retirees aged 60 years and older were voluntarily recruited and then randomly assigned to the experimental and control groups. The experimental group participated in an eight-week aquatic training program. Pain, ROM, and shoulder muscle activity were investigated using a visual analog scale (VAS), an electrogoniometer, and electromyography (EMG), respectively—twice: pre-test and post-test.

Results: Results showed significant differences between groups in pain scale, shoulder external (ER) and internal rotation (IR) ($P < 0.001$), shoulder abduction ($P = 0.002$), and muscle electrical activity of serratus anterior ($P < 0.001$), but not in shoulder flexion ($P = 0.082$) and muscle activity of upper trapezius ($P = 0.075$).

Conclusion: Our aquatic training program may profoundly impact shoulder ROM recovery and shoulder pain relief in patients with SIS. Further research is warranted to assess different and more specialized aquatic programs to improve shoulder flexion and trapezius muscle function, which were not improved by the present intervention.

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Highlights

- An eight-week aquatic training program effectively reduced shoulder pain in patients with SIS.
- The program significantly improved shoulder internal and external rotation.
- Shoulder abduction ROM also increased.
- The intervention had minimal effect on shoulder flexion.
- Serratus anterior muscle activity increased following the program.
- Upper trapezius muscle activity did not change significantly.
- Aquatic therapy may be an effective, low-impact intervention for reducing pain and improving shoulder mobility in patients with SIS.

Plain Language Summary

Shoulder impingement syndrome (SIS) is a common cause of shoulder pain, often due to overuse and strain on shoulder muscles. It affects many older adults, especially those with physically demanding jobs or active lifestyles. Treatment options for SIS range from medication and physical therapy to, in severe cases, surgery. This study explored an alternative approach: an eight-week aquatic exercise (AE) program to manage pain and improve shoulder function in patients with SIS. Participants were divided into two groups: one underwent aquatic therapy, while the other did not. The exercises, performed in warm water, were designed to relieve pain and enhance shoulder movement without putting stress on joints. The results showed that the aquatic therapy group experienced reduced shoulder pain and better range of motion (ROM), particularly in shoulder rotation and abduction. Additionally, the exercises increased activity in the serratus anterior muscle, a key muscle for shoulder movement, though it did not significantly impact the upper trapezius muscle or shoulder flexion. These findings suggest that water-based exercises can be an effective, low-impact treatment to help SIS patients manage pain and regain shoulder mobility. The study supports using aquatic therapy as a rehabilitation option for older adults with SIS, especially as an alternative to more invasive treatments like surgery.

Introduction

Shoulder disorders are a common and underestimated cause of pain and disability in geriatric patients [1], in which an increase in the number of painful sites seems to be associated with lower physical work capacity, lower physical activity [2], and considerable disruption to patients' daily life [3]. The prevalence of shoulder disorders has been reported to be high [4], accounting for 1.84 per 1000 person-years in US military personnel [5]. Research indicates that being subjected to a combination of physical workplace stresses—like overhead tasks, heavy lifting, and forceful movements—along with maintaining inappropriate postures, heightens the risk of shoulder disorders [6]. Lifetime prevalence of shoulder pain among middle-aged women was 27.6% [7]. Of all these shoulder complaints, shoulder impingement syndrome (SIS) is the

most commonly reported, accounting for 44–65% of all shoulder pain disorders and 25% of people within the UK who seek shoulder pain treatment from a general practitioner [8]. This syndrome has been found to originate from overusing the rotator cuff muscles in jobs, sporting, or other overhead activities [9], with complications occurring for different reasons such as anatomical changes in the acromion [10], and posterior capsule tightness [11]; also, this can result in slower movement speeds and increased electromyography (EMG) activity in the shoulder stabilizer muscles, to maintain motor function and reduce the engagement of larger muscles in painful regions [12], as well as contribute to scapular dyskinesia [13].

Aging is an irreversible physiological process that affects people's lives physiologically and musculoskeletal features [14] upper and lower trapezius, infraspinatus, and serratus anterior muscles was recorded. Maximum

isometric voluntary contraction (MIVC, which may subsequently result in delayed muscle recruitment, pain, and musculoskeletal disorders [12]. Therefore, when all of these age-related impairments come together in patients with SIS, the importance of developing musculoskeletal data through broader intervention strategies to guide geriatric shoulder pathologies in later life is highly demanded, as other therapeutic intervention programs have likely been insufficient [15].

Providing treatment scenarios for patients with SIS requires a better understanding of disease-related changes as well as how these changes interrelate in the musculoskeletal injury profile. Regular physical activity or specialized exercise programs may then minimize musculoskeletal changes and improve physical fitness, balance, and independence among older adults [16, 17]. Therefore, various types of physical activity, such as strength training, aerobic exercise, walking, and aquatic exercise (AE), have been abundantly recommended to maintain overall health among older adults. A recent systematic review [18] confirmed the effectiveness of AE in improving physical function in healthy older adults, and another meta-analysis [19] showed no considerable difference between the impact of combining surgery with physiotherapy versus physiotherapy alone on alleviating pain and enhancing function in patients with SIS. Other studies have highlighted the significant benefits of pool-based neuromobilization [20] and water-based exercise [21, 22] in the treatment of SIS.

A variety of treatment approaches, such as non-steroidal anti-inflammatory drugs, corticosteroid injections, physical therapy, and whatever might help to avoid surgery, are strongly recommended. The reason water-based exercise is supposed to be effective as a preventive approach for older adults is that the fundamental features of all liquids are uniform. The viscosity of water and buoyancy with a zero-gravity mechanism are the key drivers to improve muscle function in the fragile limb [23], through exploiting more integrated resistance than any other exercise does, leading to body floating and load reduction in joints and muscles during exertion [24]. Although aquatic therapy is commonly used in musculoskeletal rehabilitation, there remains a lack of substantial evidence regarding its potential effects on neuromuscular mechanisms, particularly in elderly patients with SIS. Therefore, this study aimed to investigate the effects of an aquatic training program on pain, range of motion (ROM), and electrical activity of the shoulder muscles among military retirees with SIS.

Materials and Methods

The present study was double-blind and performed as a pre-test, post-test control group design. A total of 30 retired men aged 60 and older, who were suffering from SIS and referred to a rehabilitation center to receive physiotherapeutic treatment, voluntarily participated in the study after reading flyers posted online on the rehabilitation center website by the following procedures: first, written consent was obtained from all participants, followed by a simple random sampling method according to the Morgan table. Then, a questionnaire capturing demographic characteristics, physical activity, and medical/drug consumption reports of the patients was completed through face-to-face interviews. Checking up on the participants by using clinical special tests of Hawkins-Kennedy validated with the pooled estimates of sensitivity 74% and specificity 57% [25], Neer [26, 27], and painful arc [26], and completing diagnostic imaging data extracted by CT arthrography were the next steps managed by a specialist and a qualified sonographer, respectively. The inclusion criteria included retired men between 60 and 70 years of age, having activity limitations for over one week, pain in the subacromial region, and having symptoms of SIS with an average duration of 16 months, written agreement with the research processes, having at least elementary education, and having physical and cognitive ability confirmed through documentation in their medical records. Each of these items that were not being met, along with having cervical/thoracic spine pain and glenohumeral joint instability with more than three glucocorticoid injections into the shoulder, are considered exclusion criteria. A total of 30 subjects were then randomly divided into two groups: experimental (n=15) and control (n=15) using a table of random numbers.

Intervention

The aquatic training program consisted of 16 two-time weekly sessions, consisting of warm-up (5-10 min), muscle endurance training of walking and shoulder joint movements at 50% to 65% maximum heart rate measured by a wrist-worn waterproof Apple Watch Series 4 (20-30 min), and cool-down (5-10 min). The primary intensity was 40-50% of the maximum amount of fatigue limit and was gradually increased up to 65% during the last sessions. This model of training intensity progression is scientifically approved, as high correlation coefficients (i.e. >0.7) were found between heart rate and ratings of perceived exertion in aerobic exercises [28]. This protocol was also free of any direct physical and psychological hazards for the subjects and was imple-

mented under the supervision of a well-qualified physical therapist in a warm pool adjusted to a temperature of 29 ± 2 °C according to Wilk and Joyner (2024)[29] in a rehabilitation center. Each training session comprised the following phases:

(1) Familiarization: Participants began the protocol by walking slowly in the pool while performing simple movements they were comfortable with for up to 15 minutes. This phase was only for familiarizing participants with the aquatic environment.

(2) Warming-up, first focused on the shoulders as it is known to be the most intricate joint in the entire body and needs to be properly stretched by performing a series of rotations, and ended with arm-focused movements to extend stretches throughout upper body parts. They included five sets of 10 repetitions of forward shoulder rotation with one arm only, backward shoulder rotation with one arm, forward rotation using both arms, backward rotation using both arms, lateral arm raises, and alternating arm raises, moving one arm forward. In contrast, another moves backward, and lateral arm raises ending the movement with straight arms.

(3) Special exercises of shoulder muscles via aqua-band workout in three sets of 10-15 reps on each side, supported by Batalha et al. (2018) [21], were as follows: shoulder abduction to 90°, external rotation, internal rotation (IR), band crawling, shoulder flexion 0-90°, and shoulder extension. Participants who had any background of regular water-based therapeutic training prior to our study, or any experience of acute pain urging them to stop the exercise trial and take painkiller drugs during the sessions, were excluded from the study.

(4) Cool-down stretching and movements: walking sideways, forward and backward followed by some light shoulder stretches.

All procedures applied as intervention and experiments in this study were also in accordance with the Declaration of Helsinki-Tokyo, and approved by the local ethics committee.

Diagnostic tests

Hawkins-Kennedy

To diagnose subacromial impingement, Hawkins and Kennedy (1980) studied a population of symptomatic repetitive overhead athletes, whose supraspinatus and bicipital tendons tend to be impinged in the subacromial

space of the shoulder. Given the force of repetitive overhead motions performed over a longer period of time, the subsequent gradual degeneration and tears may be seen in the rotator cuff; Hawkins established a diagnostic test known as the “impingement sign” that produces pain and facial expression. In the Hawkins-Kennedy test used in the present study, the patient was positioned sitting with the arm at 90° of shoulder flexion, supported by an examiner who internally rotated the shoulder until pain occurred. Reliability and diagnostic accuracy of this test for SIS have been reported as acceptable, with sensitivity and specificity of 0.63 and 0.62, respectively [26].

Painful arc

This test is one of the most common and simple shoulder tests to identify possible subacromial impingement syndrome. In this study, the examiner instructed the participants who were sitting on a chair to abduct the arm in the scapular plane until reaching approximately 120° of abduction—where the presence of pain between 60° and 120° and its reduction after passing 120° would be considered a positive test. This test has also been found useful as a screening test to rule out SIS, and its reliability has been acceptable for clinical use [26].

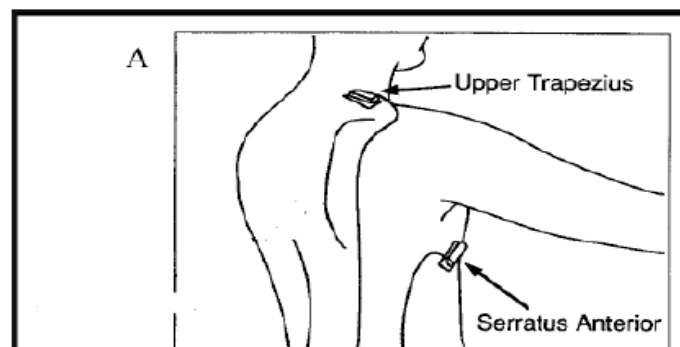
Evaluation tests

Neer test

This test was originally described in 1977 to demonstrate pain during passive abduction of the arm with the scapula stabilized. In this study, the examiner lifted the patient's arm over the scapular plane with IR to check for pain. The procedures were properly conducted in accordance with the specifications of the modified Neer test, whose specificity and diagnostic accuracy in identifying SIS have recently been shown to be 95.56% and 90.59%, respectively, by the research of Guosheng et al. (2017) [30].

Visual analog scale for pain

The visual analog scale (VAS) is commonly used as a measure to characterize the intensity of pain, and in this study was presented as a 100-mm horizontal line in which the patient's pain intensity was represented by a point between 0 “no pain at all” and 100 “worst pain imaginable.” The simplicity, reliability, and validity reported [31] make this scale an optimal tool to assess pain severity.



PHYSICAL TREATMENTS

Figure 1. Electrode placement for recording surface EMG (sEMG) (upper trapezius, serratus anterior)

Measurement of shoulder external (ER) and internal rotation

The participant was asked to lie on their back with arm abduction at 90 degrees to the trunk. The movable arm of the goniometer was then fixed to the participant's forearm axis, and its stationary arm was placed perpendicular to the ground [32]. While a supporter kept the participant's arm steady, the subject externally rotated the arm once and internally rotated the arm once until its peak to evaluate the ROM of ER rotation using a goniometer.

Measurement of shoulder flexion

The participant was asked to lie on his back with the elbow extended and the thumb pointing upward as much as possible. The stationary arm of the goniometer was placed parallel to the floor, while the movable arm was placed parallel to the lateral aspect of the arm to evaluate ROM of shoulder flexion [32].

Measurement of shoulder abduction

Similar to the previous positions, the subject was instructed to lie on their back with the arm laterally rotated alongside the body and the elbow extended, keeping the palm facing upward without any flexion or extension of the shoulder. The fixed arm of the goniometer was positioned parallel to the floor, while the movable arm was aligned parallel to the front of the arm.

Like previous positions, the subject was asked to lie on his back with his arm laterally rotated beside his body and elbow extended while his palm faced upward without flexion or extension of the shoulder. The fixed arm of the goniometer was then placed parallel to the floor, with the movable arm placed parallel to the anterior aspect of the arm [32]. Upon reaching its peak, ROM of the shoulder abduction was recorded. The concurrent validity and consistency of this method were reported as 0.976 and 0.990 for determining the values of active shoulder ROM by Carey et al. [33].

Muscle electrical activity

Surface EMG data were collected from the serratus anterior and upper trapezius muscles by applying portable ME6000 sensors over the shaved and degreased skin according to the SENIAM European protocol while participants were in a seated position and the shoulder flexed at 90° in the scapular plane with electrodes placed (1) at the 6th to 8th rib in the mid-axillary line anterior to the fibers of the latissimus dorsi muscle for the serratus anterior muscle, and (2) at the midway between 7th thoracic vertebrae and medial boarder of the scapula for the upper trapezius muscle. EMG data were analyzed by averaging three tests at 1500 Hz and at a bandwidth of 10–450 Hz, which were converted to root mean square values (filter constant of 100 ms) (Figure 1).

Table 1. General characteristics and homogeneity of subjects

Groups	Mean±SD		
	Age (y)	Weight	Height
Experimental	63±3.15	75.4±8.92	168.5±3.42
Control	64.7±3.45	75.8±8.92	179.2±5.73

SD: Standard deviation.

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Table 2. Post-test comparison of the pain scale, ER and IR, shoulder flexion and abduction

Variables	Mean±SD		Mean Diff	t	P
	Control Group	Experimental Group			
Pain	7.9±6.12	7.18±8.13	3.6	4.1	<0.001*
Internal range of motion	8.28±5.91	8.44±5.65	-16	-4.77	<0.001*
External range of motion	4.25±11.14	4.46±4.87	-6.2	-5.35	<0.001*
Flexion	19.96±116	7.12±146	-7.12	-1.91	0.082
Abduction	15.09±4.11	13.55±5.11	-1.21	-3.51	0.002*

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Statistical analysis

Data were analyzed using SPSS SOFTWARE, version 26 (IBM, USA). Pre-test and post-test comparisons within groups were conducted using paired t-tests, and comparisons between the experimental and control groups were analyzed using independent t-tests. The data were checked for normality using the Shapiro-Wilk test, and results were presented as Mean±SD. For all analyses, a $P<0.05$ was considered statistically significant.

Results

Table 1 presents the general characteristics and homogeneity of the participants, including their height, weight, and age, in both the experimental and control groups. The data are presented as Mean±SD to reflect the average characteristics and variability within each group.

According to Figure 2, a significant difference was observed in post-test pain scale ($P<0.001$) between groups.

As shown in Figure 3 and Table 2, the results revealed a significant difference in post-test ER and IRs between groups ($P<0.001$).

While there was no considerable difference in post-test shoulder flexion between groups in Figure 4 ($P=0.082$), Figure 5 and Table 3 illustrate a significant increase in post-test shoulder abduction of the experimental group compared to its Pre-test and control data ($P=0.002$).

Finally, Figure 6 and Table 3 show a significant post-test difference in serratus anterior muscle activity in the experimental group ($P=0.000$), while there was no considerable difference in upper trapezius muscle activity in the experimental group ($P=0.75$).

Discussion

The results of the present study demonstrated the beneficial effects of an aquatic training program on neuromuscular profile - from relieving pain and improving ROM in the shoulder to restoring muscle function of the serratus anterior - which would seemingly help patients with SIS over their routine activities, particularly

Table 3. Post-test comparison of the pain scale, shoulder external and internal rotation, shoulder flexion and abduction

Variables	Mean±SD		Mean Diff	t	P
	Control	Experimental			
Pain	79±12.6	18.7±13.08	60.3	10.47	0.000*
Internal ROM	28.8±8.95	44.8±5.65	-16	-4.77	0.000*
External ROM	25.4±11.14	46±4.87	-20.6	-5.35	0.000*
Flexion	116±19.96	128.7±6.46	-12.7	-1.91	0.082
Abduction	118.4±15.09	139.5±11.5	-21.1	-3.51	0.002*

*Statistical significance.

PHYSICAL TREATMENTS

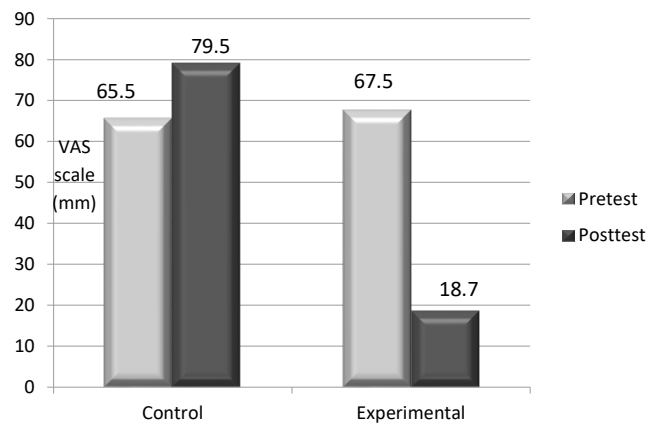


Figure 2. Pre-test and post-test comparison of the pain scale between groups

pain-free shoulder movements. However, this aquatic training protocol was found not to affect upper trapezius activity and shoulder flexion, which may require scientific justification.

Shoulder disorders have always been the most common among regional pain syndromes and cause morbidity [6]. One of the primary factors contributing to the increased prevalence of this disorder across all age groups is regular exposure to a combination of physical workplace stresses, such as overhead tasks, heavy lifting, and forceful activities, particularly when individuals perform tasks that require circular arm movements in awkward postures.

Psychological and psychosocial factors may also be associated with upper limb musculoskeletal disorders, and this is even going to be much worse now as a result of the psychological fallout of the COVID-19 pandemic [34]. One of these shoulder musculoskeletal disorders is SIS, for which treatment is recommended to be mostly scheduled through conservative strategies.

In recent years, many studies have tried different non-pharmacological therapeutic modalities, including exercise programs for the rotator cuff and scapular muscles, demonstrating neuromuscular adaptations with improvements in muscle activity [35]. It presents a strong recommendation for exercise therapy as the first-line treatment to improve pain, mobility, and function [36], after a variety of manual therapy techniques incorporated with balanced ligamentous tension [37], modification of everyday activities [38], and electrotherapy as the next most easy-to-reach ways to cope with SIS symptoms [39]. However, despite all this moderate to strong preliminary evidence suggesting the use of different methods in agreement with the present study's findings in the treatment of SIS, therapeutic strategies are still lacking due to poor understanding of the neurophysiological and molecular mechanisms involved in SIS and exercise specifications. Some of the water-induced mechanical and reflex effects, though would seemingly be a reason to put hydrotherapy into treatment priorities for patients with SIS, as it has been recently found that a water-based program may be used as preventive approach to improve

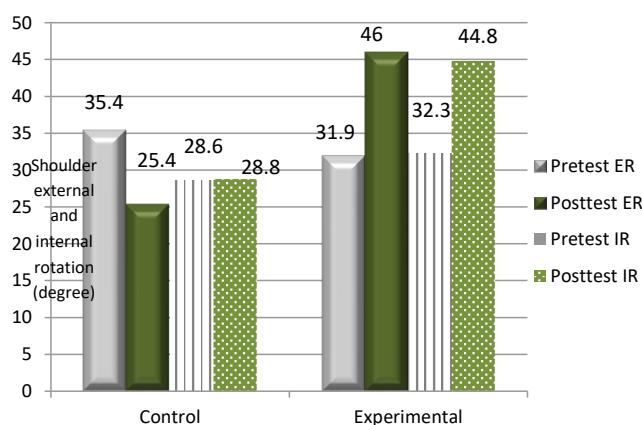


Figure 3. Pre-test and post-test comparison of the ER and R between groups

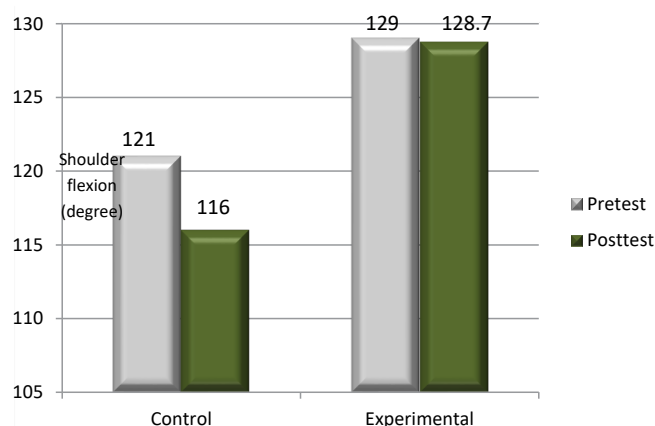


Figure 4. Pre-test and post-test comparison of the shoulder flexion between groups

PHYSICAL TREATMENTS

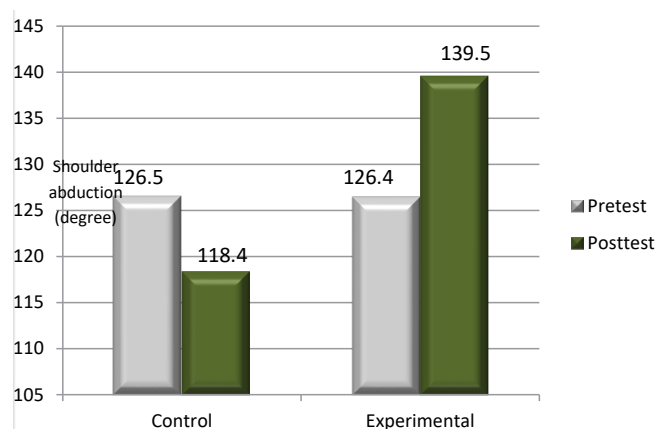


Figure 5. Pre-test and post-test comparison of the shoulder abduction between groups

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fall risk awareness in other adults with musculoskeletal disorders [40]. A recent study whose training protocol was similar to the present study has also outlined that water-based aerobic training program induced improvements in functional capacity and quality of life in older adults [41]. In line with these findings, recent reviews have explored current perspectives on water therapy and

the physiological mechanisms that support its use in pain management. These reviews indicate that water therapy is effective in alleviating the clinical symptoms of fibromyalgia syndrome, particularly pain, which is a defining characteristic of this condition [24]. Even people with neurological disorders, such as Parkinson's and severe traumatic brain injury have also been reported to some-

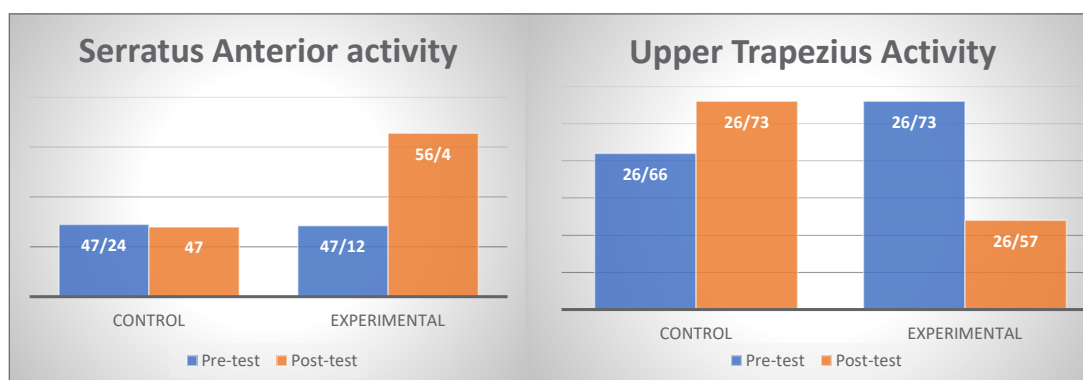


Figure 6. Pre-test and post-test comparison of the muscle activity of serratus anterior and upper trapezius between groups

PHYSICAL TREATMENTS

how benefit from undertaking hydrotherapy sessions [42, 43], which shows some special features of this therapy focused on principles, such as floatability, hydrostatic pressure, viscosity, and buoyancy, can efficiently work on neural signaling/networks to block nociceptors throughout the spinal cord [44].

This neural repair process will support the body by increasing blood flow, aiding in the removal of allogeneic chemicals to promote muscle relaxation, and ultimately helping to relieve pain by decreasing peripheral edema and sympathetic nervous system activity. However, it is important to note that the neural benefits induced by hydrotherapy will not be achieved immediately; they require time and careful planning [45], as long as the aquatic protocol is being proposed to patients with end-stage dementia, which has led to their clinical progress [46].

One probable reason for the lack of increase in upper trapezius activity in this study is the force couple function between the upper trapezius and serratus anterior [47]. Specifically, the movement patterns provided to the patients likely elicited more contractions in the anterolateral movement of the scapula along the ribcage, primarily activating the serratus anterior rather than the upper trapezius [48]. There must also be some other reasons why our hydrotherapy protocol has failed to significantly affect the ROM of shoulder flexion, unlike the considerable effects reported on pain scale, ER and IR, and abduction. First, unsurprisingly, hydrotherapy methodologically is characterized by the ability to assist in rehabilitation and recovery from serious injury, as a very low-to-moderate intensity complementary therapy, which in some cases seems not to work enough to affect muscle tensions, as it inherently does for pain and ROM by loosening muscle stiffness/tension [49]. Therefore, this study would suggest that a different hydrotherapy program with more specialized and challenging movements/stimulus must be considered to properly affect neural networks as well as muscle activity of the trapezius muscle group. Second, as a recent review has shown, water-based walking training would naturally provoke lower muscle activation compared to land walking, which again shows that our protocol may not have provided enough training load when considering patients' baseline one-to-one neuromuscular fitness [50]. Ultimately, a small sample size of 30 individuals was another factor that might have negatively impacted final findings, as with any other study whose sample size is limited for economic and other relevant reasons. Our findings, therefore, would be more robust if all these above-mentioned parameters were taken into consideration.

Conclusion

To schedule a long-term nonpharmacological therapeutic program for patients with SIS, one must be careful about the extent of their disease, disability intensity, age, and other health characteristics. Employing an exercise training intervention, such as hydrotherapy with special characteristics and implementation features to support patients' weight while improving pain and ROM of the shoulder, could be considered as a part of a rehabilitation program for patients with SIS. However, further studies are required to support whether this therapy alone, with the modifications needed, would be enough to act as strength training to improve neuromuscular profile as well as ROM, or whether relying on it as a complementary therapy would be more rewarding.

Ethical Considerations

Compliance with ethical guidelines

All procedures applied as intervention and experiments in this study were also in accordance with the Declaration of Helsinki-Tokyo. This study was approved by the Research Ethics Committee of [Academic Center for Education, Culture and Research \(ACECR\)](#), Tehran, Iran (Code: IR.ACECR.IBCRC.REC.1400.020).

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Authors' contributions

Conceptualization and analysis: Manijeh Soleimanifar; Study design and writing: Manijeh Soleimanifar and Mostafa Sarabzadeh; Data collection: Mehdi Pakdel; Data analysis: Zahra Sadat Asadi; Data interpretation: Manijeh Soleimanifar, Mostafa Sarabzadeh, and Zahra Sadat Asadi; Final approval: All authors.

Conflict of interest

The authors declared no conflict of interest.

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