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Effectiveness of proprioceptive neuromuscular facilitation pattern on upper extremity and scapula in patients with adhesive capsulitis: a single-centre assessor-blinded randomised controlled trial (RCT)

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Abstract

Background Adhesive capsulitis (AC) is a progressive inflammatory condition of the shoulder that causes functional limitations and leads to long-term disability. The study aimed to elicit the effectiveness of proprioceptive neuromuscular facilitation (PNF) compared to standard physiotherapy approaches on AC.

Methods An assessor-blinded single-centre randomised control trial (RCT) was carried out on 80 AC patients between May 2022 and December 2023 in Bangladesh. Random assigned and concealed allocated patients were recruited equally ($n=40$) to each PNF and conventional capsular stretching group. The experimental group received a PNF approach, and the control group received capsular stretching to the affected shoulder for 24 sessions in 6 weeks. Both groups received electrical modalities as standard treatment. The primary outcome was pain measured by the numeric pain rating scale (NPRS) and range of motion in a universal goniometer. The secondary outcome was functional limitation measured by the shoulder pain and disability index (SPADI). As per the distribution of data, non-parametric tests were employed to analyse the superiority between and within groups with intention-to-treat analysis.

Results Baseline compatibility was noted in all the key variables ($p>0.05$). Both PNF and capsular stretching had a decrease in pain compared to baseline in all capsular pattern positions ($p<0.001$), and PNF had more significant improvement compared to control ($p<0.001$). Both groups had equal improvement in shoulder ROM ($p<0.001$) except abduction ($p<0.05$). Both groups had improvements in disability ($p<0.05$), and PNF had statistical superiority of improvement ($p<0.001$).

Conclusions The findings of this study support the potential of PNF intervention for 6 weeks as a treatment for shoulder adhesive capsulitis, showing improvements in pain, ROM and functional disability. However, further multicentre trials with a follow-up design are needed to fully understand the superiority of PNF on shoulder AC, encouraging continued engagement in this area of research.

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Keywords Adhesive capsulitis, Proprioceptive neuromuscular facilitation (PNF) pattern, Upper extremity, Standard physiotherapy

Background

Adhesive capsulitis (AC) is a musculoskeletal disorder characterised by painful limitation of upper limb activities that is associated with a combination of pain and limitation of passive movements [1]. The joint capsule of the shoulder becomes inflamed and gradual limitation of shoulder range of motion occurs; the condition is often explained as a stiff shoulder [2]. Aetiology is unknown but cardiovascular disease, cervical spine conditions, diabetes, sudden trauma, stroke, Parkinson's disease, coronary artery bypass grafting (CABG) and humeral fractures are often associated with AC [3]. Moreover, some intrinsic factors such as injuries to the rotator cuff muscles, long head of the biceps tendon, joint inflammation and calcification of the biceps tendon and other tendons may contribute to AC [4].

AC is believed to be a self-limiting condition lasting 2 to 3 years; some studies have reported that up to 40% of patients have persistent symptoms and stiffness even after 3 years because pain and inflammation are self-remitting but the muscle atrophy and joint pathology are consistent if not treated [5]. It is difficult to find an actual population prevalence of AC; the incidence is evident between 3 and 5% of the normal population in a given year [6, 7]. AC greatly affects between 40 and 60 years of aged people, with females being higher than males [6]. About 20 to 30% of people having AC in one shoulder develop symptoms in the opposite shoulder after a certain period [7].

The biomechanical abnormalities of the scapulo-humeral rhythm and muscle control of the prime movers of the shoulder especially the deltoid and rotator cuff play vital role in developing AC associated musculoskeletal issues [8]. Moreover, the painful movement contributes to kinesiophobia that gradually hinders the flexibility of the muscles of shoulder and causes disruption to the scapula-humeral synergistic relationship [9]. The medical treatment for AC involves the use of nonsteroidal anti-inflammatory medications, short-term oral corticosteroids, intra-articular corticosteroid injections, physiotherapy, acupuncture and hydro-dilatation [10]. The role of physiotherapy is to facilitate the arthrokinematic motion of glenohumeral joint, acromio-clavicular joint and improve the osteokinematics of these joints including scapula-thoracic articulation [11]. The gradual mobility and motion facilitate a range of motion (ROM), mimic the inflammatory mediators and break down the scars of the joint capsule [12]. The convex-concave rule explains the necessity of neuromuscular flexibility in improving the movement limitations in capsular patterns [13, 14]. There are a couple of concepts in the management of AC; proprioceptive neuromuscular facilitation (PNF) is one of them [15].

PNF has three theoretical mechanisms, autogenous inhibition, behaviour modification and stress relaxation [16]. The gate control theory of PNF is explained to enhance ROM that facilitates muscle activation [17]. Evidence suggests PNF treatment increases blood flow by up to 71% in the administered muscles and eases subjective pain by up to 16% from baseline [15]. PNF added with conventional stretching and mobilisation can decrease subjective pain by up to 21% [18]. In AC, PNF effects on stretch reflex mechanism and facilitates muscles by utilising diagonal movement patterns to activate the bi-articular muscles of the shoulder [19].

PNF is a promising treatment among therapeutic approaches to improve pain, muscle flexibility and increase ROM [18]. An all-encompassing strategy for AC management necessitates methods to enhance the effective functioning of the upper limbs, taking into account both the movement and stability of the scapula. The scapula pattern of proprioceptive neuromuscular facilitation (PNF) simultaneously engages both upper extremity movement patterns and scapular motions [20]. The effects of PNF on the shoulder have been investigated in some studies [5, 21]. Nevertheless, there is a lack of research that explores the impact of upper extremity and scapular proprioceptive neuromuscular facilitation (PNF) exercises in the rehabilitation of the acromioclavicular (AC) joint. Hence, the objective of this study was to assess the efficacy of the proprioceptive neuromuscular facilitation pattern (PNF) in treating adhesive capsulitis by comparing its efficiency on the upper extremity and scapula with traditional physiotherapy. Our hypothesis was PNF alone might have a superior effect compared to conventional exercise therapy in improving pain, muscle flexibility, ROM, shoulder function and disability in adhesive capsulitis (AC).

Methods

Study design

An assessor-blinded randomised controlled trial (RCT) was conducted in the outpatient physiotherapy musculoskeletal unit at the Department of Physiotherapy at the Centre for the Rehabilitation of the Paralysed (CRP), Savar, Dhaka 1343, Bangladesh, from May 2022 to December 2023. The population of interest was people having adhesive capsulitis diagnosis in hospital records.

Recruitment of patients and randomisation

The names and contact details of patients who had adhesive capsulitis were retrieved from hospital records of outpatient department software named Patient Data Management System (PDMS) at CRP. They were population frames. Then, patients were then contacted via a telephone call to invite them to the study. Patients interested in the study were screened against the inclusion/exclusion criteria using a telephone-administered questionnaire. The inclusion criteria were (1) adults aged between 21 and 70 years [22], (2) re-diagnosis as unilateral adhesive capsulitis (AC) by a qualified physiotherapist according to the Cyriax concept capsular pattern theory and (3) patient with shoulder pain at least 1 month but not more than 3 months [5]. Patients were excluded if they reported (1) a history of using drugs due to adhesive capsulitis and surgery on the shoulder or manipulation under anaesthesia, (2) neurologic deficits affecting shoulder functioning during ADL or diagnosed as brachial plexopathy by nerve conduction study (NCS), (3) pain or disorders of the cervical spine, elbow, wrist or hand and (4) other conditions involving the shoulder as rotator cuff tear or tendinitis, etc. [5]. Eligible participants were referred to the musculoskeletal unit one and two of the Department of Physiotherapy, CRP, for further screening with a concealed random allocation after the screening process. Before going for the treatment in every unit, there was a separate cubicle for the blinded assessor to complete the informed consent and baseline assessment. After the end of the treatment protocol, each patient re-entered the same room for outcome evaluation. A computerised random allocation technique using Microsoft Excel 2013 was used to assign the participants in both groups. The Consolidated Standards of Reporting Trial (CONSORT) was supplied in Fig. 1.

Sample size calculations

The sample size was estimated using statistical power analysis processes with the assistance of the PASS 2005 program (NCSS, Kaysville, UT, USA) [23]. Based on a power analysis, it was determined that each group would require 30 individuals in order to achieve a power of 90% and maintain a type I error rate of 5%. To account for a dropout rate of 20% in the trial, we enrolled 40 participants in each group to guarantee a power of 90%. The power analysis conducted for our study revealed a statistical power of 90%, with adhesive capsulitis being the key outcome measure.

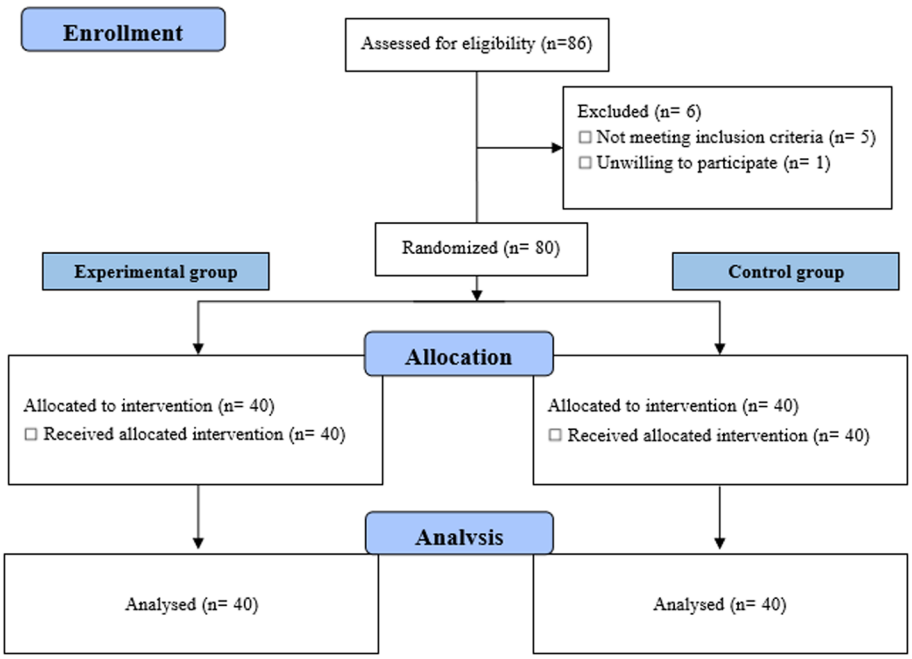

Fig. 1 CONSORT flow diagram

Outcome measurement

Numerical pain rating scale

As the primary outcome, we used the numeric pain rating scale (NPRS). The NPRS is a linear scale where the individual being evaluated indicates the intensity of their pain by marking a point on the line. The endpoints of the linear scale correspond to the farthest thresholds of pain, where 0 indicates the absence of pain, 1–3 denotes mild discomfort, 4–6 signifies moderate pain and 7–10 represents the most excruciating agony ever encountered [24].

Goniometer

To measure another primary outcome, goniometer was used to measure ROM. We assessed the range of motion at the initial assessment and post-test assessment with the same goniometer to ensure consistency. A goniometer is a valid and reliable tool for measuring ROM globally [25].

Shoulder pain and disability index (SPADI)

Additionally, we assessed function, pain level and disability using the SPADI scale as a supplementary measure. The system is composed of two sections, one dedicated to pain-inducing activities and the other focused on functional tasks, the pain dimension comprises 5 inquiries regarding the intensity of an individual's pain. The assessment of functional activities involved the use of eight specific questions aimed at determining the level of difficulty that individuals experience in performing various daily tasks that require the use of their upper limbs. The SPADI can be completed by a patient in a time frame of 5 to 10 min and is the only dependable and accurate measure specifically designed for assessing the shoulder [26].

Intervention

Experimental group

Within this group, we employed the proprioceptive neuromuscular facilitation technique (PNF) specifically for the upper extremity [22]. The patient was resting on their back with their arms positioned alongside their torso. The individuals were instructed to loosen the tension in their shoulder muscles. The therapist positioned themselves next to the impacted side of the patient. The technique used was the "flexion-abduction-external rotation" (D2F pattern) with a straight elbow pattern of proprioceptive neuromuscular facilitation (PNF) using the "hold relax" technique. This equipment is designed to provide relaxation by using isometric contractions against maximum resistance. It is intended to enhance the passive range of motion and reduce pain. The individual executed isometric contractions for 5–8 s, applying maximal resistance. These contractions were specifically targeted to prevent the opposing muscles from contracting and included a rotation at the point of maximum joint movement. The technique was done multiple times until reaching the point of movement restrictions and then advanced to additional stages. When implementing the D2F pattern with a straight elbow pattern of PNF, the therapists used their hands to grasp the patient's upper limb on the side opposite to the hip. The patient's shoulder was positioned in extension, adduction and internal rotation, while the elbow was extended and the forearm was pronated. The physiotherapist thereafter instructs the patient to elevate his hand above his head. The patient endeavoured to execute this motion by engaging in shoulder flexion, abduction and external rotation. During these movements, the therapist would stabilise the patient's arm with his other hand (Fig. 2). The duration of treatment was 15 min for every 10 sets of PNF. There were 5 repetitions per set, with 5-s hold time and 2 s of rest time. There was no progression of sets. Treatment was provided for 6 weeks and 4 sessions per week in alternative days.

The second technique was the proprioceptive neuromuscular facilitation technique for the scapula and it has two patterns (Fig. 2). Firstly anterior elevation and posterior depression. The patient reclines on the unaffected side, while the therapist positions themselves behind the patient, with one hand resting on the upper edge of the scapula and the other on the lower corner of the scapula. The therapist provided the patient with manual resistance and directed them to perform scapular movements by pushing up and down. The duration of treatment was 7 min for 5 sets. Treatment repetitions were 5 repetitions/set, with hold time for 5 s and rest time for 2 s. The treatment was given for a total of 6 weeks, 4 sessions per week.

Additionally, in case of posterior elevation and anterior depression, the patient is positioned on the side that is not affected. The therapist stood behind the patient, with one hand positioned on the superior border of the scapula and the other on the inferior angle of the scapula. The patient received instructions to exert force in a backward direction and apply pressure to the front of the scapula while the therapist provided resistance. The duration of treatment was 8 min for 5 sets. Repetitions were 5 repetitions/set, hold time for 5 s and rest time for 2 s. The treatment was provided for a total of 6 weeks, 4 sessions per week.

Control group

The control group was given conventional physiotherapy only according to the patient's response to treatment. Both groups underwent a standard intervention program consisting of conventional physiotherapy techniques, such as capsular stretching, accessory movements, pendulum

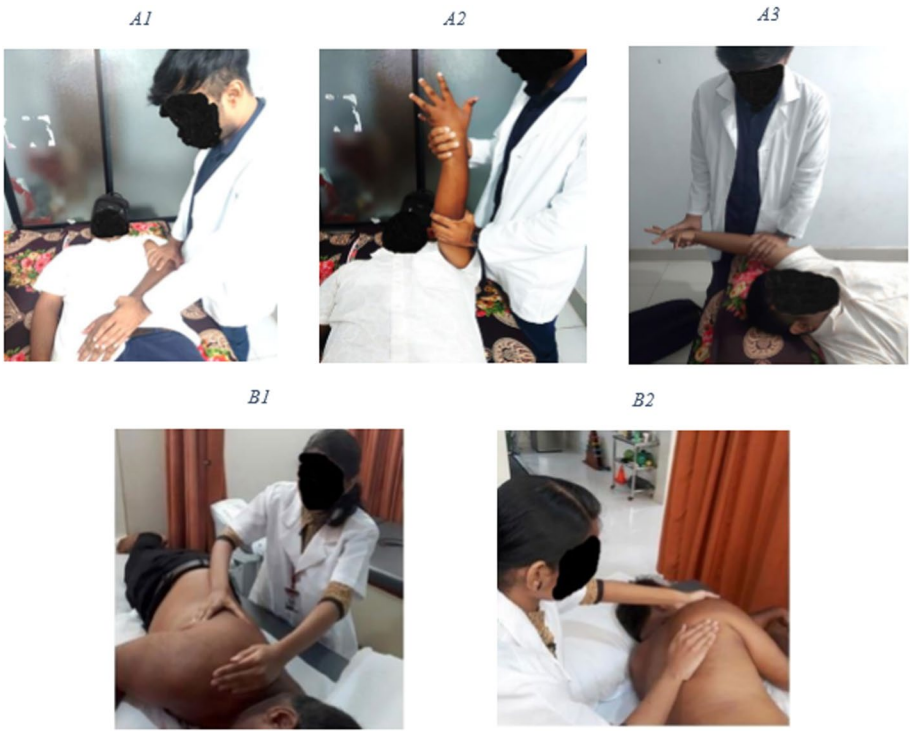

Fig. 2 PNF application procedure for upper extremity (**A1**–**A3**) and scapula (**B1**, **B2**)

exercise, pulley exercise, infrared radiation applied to the affected shoulder for 20 min and ultrasound therapy tailored to the patient's condition and prescribed frequency. The control group received 30 min of treatment per session for 4 times a week for up to 6 weeks. The control treatment was according to the standard physiotherapy exercise protocol set by the outpatient musculoskeletal unit, Department of Physiotherapy, CRP, Savar, Dhaka 1343, Bangladesh.

A step-by-step table detailing the treatment procedures for both the experimental and control groups:

Group	Step	Procedure	Duration	Details
Experimental group	1	"Flexion-abduction-external rotation" (D2F pattern) PNF pattern using the "hold relax" technique	15 min	10 sets, 5 repetitions/set, 5-s hold, 2-s rest
	2	Anterior elevation and posterior depression PNF pattern of scapula	7 min	5 sets, 5 repetitions/set, 5-s hold, 2-s rest
	3	Posterior elevation and anterior depression PNF pattern of scapula	8 min	5 sets, 5 repetitions/set, 5-s hold, 2-s rest
Control group	1	Capsular stretching	5 min	Part of a standard physiotherapy intervention
	2	Accessory movements	4 min	Part of a standard physiotherapy intervention
	3	Pendulum exercise	4 min	Part of a standard physiotherapy intervention
	4	Pulley exercise	4 min	Part of a standard physiotherapy intervention
	5	Infrared radiation applied to the affected shoulder	3 min	Included in standard physiotherapy program
	6	Ultrasound therapy tailored to the patient's condition and prescribed frequency	10 min	Included in standard physiotherapy program

Statistical analysis

A parametric test was used to analyse interval or ratio data and a non-parametric test was used to analyse the nominal/ordinal data. The normality of data was checked by the Kolmogorov–Smirnov test. The value of the

Kolmogorov–Smirnov test is less than 0.05, which indicates that the data distribution was not normal [27]. So, descriptive statistics like median and interquartile range (IQR) were used to analyse the sociodemographic information where the between-group mean difference analysis of pain intensity, improvement of ROM of different movements of shoulder and improvement of functional performance of the participants was analysed by Mann–Whitney *U* test and the within-group analysis of pain intensity, improvement of ROM of different movements of shoulder and improvement of functional performance of the participants was done by Wilcoxon signed rank test. The alpha value was set as $p < 0.05$.

Results

Demographic and clinical characteristics

The sociodemographic and clinical information are summarised in Table 1. The median age of the participants in the experimental group was 48 (43.25 to 60) and in the control group 51 (45 to 57) years. In both groups, the male participants number was the maximum, 52.5% ($n = 21$) in the experimental group and 62.5% ($n = 25$) in the control group. Regarding educational status, most participants 32.5% ($n = 13$) completed SSC in the experimental group whereas 37.5% ($n = 15$) completed primary education in the control group. Most of the participants in the experimental group lived in the rural areas 47.5% ($n = 19$) but in the control group, they were mostly from urban areas, 42.5% ($n = 17$). Except for housewives, most of the participants were service holders in both groups, 27.5% ($n = 11$) in the experimental group and 25.0% ($n = 10$) in the control group. Regarding clinical characteristics, most of the participants had direct trauma in both groups, 60.0% ($n = 24$) in the experimental group and 62.5% ($n = 25$) in the control group. Hypertension was the most common chronic illness in both groups, 47.5% ($n = 19$) in the experimental group and 45.0% ($n = 18$) in the control group.

Table 1 Demographic and clinical characteristics of participants at baseline

Variables	Experimental group ($n = 40$)	Control group ($n = 40$)	*p*
Demographic characteristics			
Age in years [median (IQR)][a]	48 (43.25 to 60)	51 (45 to 57)	0.91*
Gender [% (*n*)][b]			
Male	52.5 (21)	62.5 (25)	0.33
Female	47.5 (19)	37.5 (15)	
Education [% (*n*)][b]			
Primary education	22.5 (9)	37.5 (15)	0.41
Completed SSC	32.5 (13)	22.5 (9)	
Completed HSC	22.5 (9)	22.5 (9)	
Bachelor and above degree	22.5 (9)	17.5 (7)	
Living area [% (*n*)][b]			
Urban	27.5 (11)	42.5 (17)	0.09
Rural	47.5 (19)	37.5 (15)	
Semi-urban	25.0 (10)	20.0 (8)	
Occupation [% (*n*)][b]			
Day labourer	15.0 (6)	22.5 (9)	0.72
Service holder	27.5 (11)	25.0 (10)	
Businessman	22.5 (9)	17.5 (7)	
Housewife	35.0 (14)	35.0 (14)	
Clinical characteristics			
History of trauma [% (*n*)][b]			
Over use trauma	30.0 (12)	32.5 (13)	0.51
Direct trauma	60.0 (24)	62.5 (25)	
Psychological trauma	10.0 (4)	5.0 (2)	
Chronic illness [% (*n*)][b]			
Diabetic mellitus	17.5 (7)	20.0 (8)	0.46
Hypertension	47.5 (19)	45.0 (18)	
Heart disease	20.0 (8)	12.5 (5)	
Obesity	15.0 (6)	22.5 (9)	

IQR Interquartile range, *SSC* Secondary school certificate, *HSC* Higher secondary certificate

* *baseline compatible*

[a] *Mann-Whitney U test*

[b] *Pearson chi-square test*

Pain severity

Both group participants were screened for their pain severity in the shoulder joint (Table 2). Based on some common activities, patients were evaluated for pain in resting position where the within-group analysis showed significant change was found in both experimental group and control group ($p < 0.001$). In the case of pain during rising arm sideways, within-group analysis showed significant change was found in both the experimental group and control group ($p < 0.001$) and for pain during combing hair, within-group analysis showed significant change was found in both experimental group and control group ($p < 0.001$). For between-group analyses, significant changes were found in all three activities of the shoulder joint ($p < 0.001$).

Range of motion (ROM)

Limitation in shoulder joint was checked for only three movements: shoulder abduction, lateral rotation and medial rotation. A significant median difference was observed after providing treatment between control and experimental group participants in terms of shoulder lateral and medial rotation movement ($p < 0.001$) but not for shoulder abduction ($p > 0.05$) (Fig. 3).

Table 2 Baseline and after-treatment status of pain severity by numeric pain rating scale (NPRS)

Outcome group	Baseline	After treatment	Within group change scores		Between group change scores	
	Median (IQR)	Median (IQR)IQR	*Z*	*p*	*Z*	*p*
Pain at resting position						
Experimental	5 (3 to 6)	1 (0 to 2)	5.544	0.001*	6.052	0.0001*
Control	6 (3 to 6)	2 (2 to 3)	5.047	0.001*		
Pain during rising arm sideways						
Experimental	9 (8 to 9)	2 (1 to 2)	5.489	0.001*	7.518	0.0001*
Control	8 (8 to 9)	5 (5 to 6)	5.358	0.001*		
Pain during combing hair						
Experimental	9 (8 to 9)	2 (1 to 3)	5.542	0.001*	4.990	0.0001*
Control	9 (7 to 9)	5 (2 to 5)	5.256	0.001*		

* Significant at 95% confidence level; within-group analysis: Wilcoxon rank test; between-group analysis: Mann-Whitney *U* test

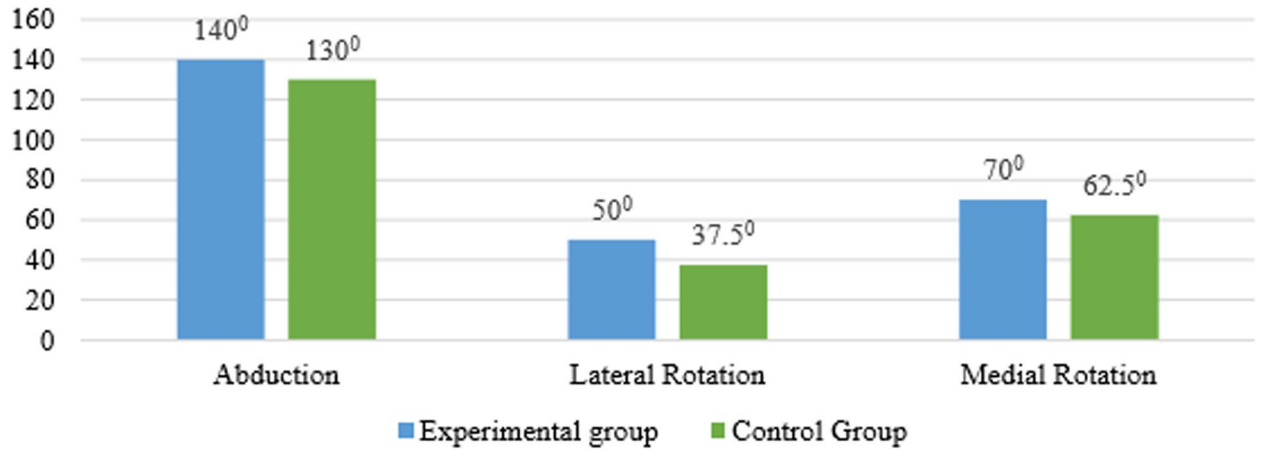

Fig. 3 Evaluation of median difference in the ROM of shoulder movements after treatment

Shoulder pain and disability index

Participants were screened by shoulder pain and disability index at baseline and after completing the whole treatment sessions (Table 3). In the case of pain intensity, within-group analysis showed significant change was found in both the experimental group ($p < 0.001$) and control group ($p < 0.05$). In the case of disability level, within-group analysis showed significant change was found in both the experimental group ($p < 0.001$) and control group ($p < 0.05$) and for total SPADI score, within-group analysis showed significant change was found in both experimental group ($p < 0.001$) and control group ($p = 0.021$). For between-group analyses, significant changes were found in all parameters of SPADI ($p < 0.001$).

Discussion

This study was carried out to determine the effect of PNF compared to standard physiotherapy in adhesive capsulitis in a Bangladeshi setting. The primary objective was to determine the superiority of PNF in relieving pain, improving ROM and improving the functional and disability status of AC. The objective was successfully examined with statistically significant superiority results in the PNF group in all indicators. In consideration, it was revealed that the mean age of the participants was 50 (44.25 to 60) years and among men 21.3% were government and non-government service holders and among women 42.5% were housewives. As for major working positions, 66.3% worked in a sitting position and 21.3% worked in a standing position. Among the participants, 55% had a history of overuse injury. These incidences are indicating the relationship between age and working characteristics with adhesive capsulitis. A randomised controlled study conducted on 36 participants by Shabbir and colleagues [22] revealed that the mean age of the participants was 53.94 ± 9.38 and only 11 of 36 patients (30.6%) with adhesive capsulitis were still working in

Table 3 Baseline and after-treatment scores for pain, disability and total SPADI score by using shoulder pain and disability index (SPADI)

Outcome group	Baseline	After treatment	Within group change scores		Between group change scores	
	Median (IQR)	Median (IQR)	*Z*	*p*	*Z*	*p*
Pain intensity						
Experimental	72 (64.50 to 76)	26 (22 to 30)	5.519	0.001*	7.648	0.0001*
Control	75 (68.50 to 79.50)	50 (46 to 54)	2.820	0.032*		
Disability level						
Experimental	64.50 (60 to 69.75)	22 (18 to 25)	5.516	0.001*	7.696	0.0001*
Control	67 (62 to 74)	44.50 (41 to 48)	2.685	0.028*		
Total score						
Experimental	67 (62 to 71)	23 (20 to 27)	5.517	0.001*	7.707	0.0001*
Control	70 (64.75 to 75)	46.50 (43 to 49)	2.515	0.021*		

*Significant at 95% confidence level, within-group analysis: Wilcoxon rank test; between-group analysis: Mann-Whitney U test

various jobs and sectors actively, rest of them were not working (15 retired—10 unemployed) as of 69.4%.

This study demonstrated the efficacy of scapular proprioceptive neuromuscular facilitation (PNF) exercises in reducing pain intensity during rest, arm abduction and hair combing. Additionally, the study revealed that the PNF group had greater improvement in shoulder range of motion compared to the control group. However, the distinction was not statistically significant for abduction movements. Nevertheless, it was shown to be statistically significant for external and internal rotation movements. Additionally, significant improvements were observed in functional performance, such as discomfort and handicap status. In a randomised controlled study conducted by Choi and colleagues [21], it was found that both the scapular proprioceptive neuromuscular facilitation (PNF) group and the conventional physiotherapy group showed significant improvement. However, the PNF group had a greater reduction in pain and disability compared to the conventional group, as indicated by the mean value.

It was elicited that upper extremity and scapula PNF patterns provide additional benefit in only abduction movement of the shoulder, although do not provide benefit in resting pain, pain in an activity like raising the arm sideways or combing hair, internal and external rotation movement parameters in management of adhesive capsulitis. The within-group analysis of the experimental group revealed a significant reduction in pain at a statistically significant level of $p < 0.001$. The underlying idea here is that PNF (proprioceptive neuromuscular facilitation) has been scientifically demonstrated to generate a pain-relieving effect by means of a gate control mechanism. The PNF approach applies pressure and proprioceptive inputs that reach the spinal level, effectively inhibiting the entry and transmission of pain signals [28, 29].

In this study, there is a significant improvement in shoulder movement especially in internal rotation and external rotation found in the post-interventional increase of range of motion in the PNF group. This can be occurred due to an increment in excitability and a decrease in response time. In their randomised study, Lee and colleagues [30] found that the combination of general physiotherapy techniques (including a 20-min hot pack, 5 min of US therapy and 20 min of TENS) was effective in improving pain and features associated with myofascial pain syndrome. They observed this positive outcome in approximately 32 participants who underwent proprioceptive neuromuscular facilitation (PNF). The hold-relax proprioceptive neuromuscular facilitation (PNF) technique was implemented to induce relaxation in the upper trapezius muscle, while the reverse PNF techniques were utilised to stabilise the scapula muscles. One session of scapular proprioceptive neuromuscular facilitation (PNF) has been shown to effectively enhance shoulder range of motion in flexion and abduction [14, 31].

From this current study, the principle of the PNF pattern was a hold-relax technique in which the patient was told to hold a certain position for a specific amount of time in both the upper extremity and scapular pattern followed by a relaxation period. In their work, Rahman and colleagues [32] utilised rhythmic initiation and repetitive contraction of the scapula's anterior elevation and posterior depression as the strategies. Additionally, they clarified that the activation of the Golgi tendon organ, which triggers reflexive muscle relaxation, is likewise accountable for the augmentation of range of motion (ROM).

Another factor that enhances shoulder function is the targeted application of the proprioceptive neuromuscular facilitation technique, which aims to alleviate

tension in the muscles around the shoulder and limited joints, resulting in rapid improvements in range of motion. A randomised controlled trial conducted by Balci and colleagues [5] found that the application of the rhythmic initiation approach in scapular proprioceptive neuromuscular facilitation (PNF) enhances motion, induces relaxation in patients, enhances coordination and restores normal motion. The technique of repetitive contractions facilitates a rise in both the active range of motion and strength, while also guiding the patient's movement towards the desired motion. Therefore, the present study confirms the effectiveness of the PNF technique in enhancing both the quality of life and the recovery process for individuals with adhesive capsulitis. Nevertheless, scapular PNF workouts did not directly induce these enhancements. The study posits that PNF has the potential to be efficacious when implemented alongside a consistent rehabilitation regimen in the long run. In their study, Jung and Chung [33] examined the effects of the scapular pattern and hold-relax technique of proprioceptive neuromuscular facilitation (PNF) on the range of motion (ROM) and discomfort in a group of 30 individuals with acromioclavicular (AC) issues. Over 4 weeks, they attended to the individuals experiencing discomfort and found that proprioceptive neuromuscular facilitation (PNF) proved to be efficacious in improving range of motion (ROM) and reducing pain. Patient health education also plays an essential role in managing adhesive capsulitis. Delivering clear and comprehensible information about the condition equips patients with knowledge, empowering them to take an active role in their recovery [34].

Overall, this research study has demonstrated that proprioceptive neuromuscular facilitation (PNF) is superior to conventional or standard physiotherapy protocols in terms of pain reduction, improvement in range of motion (ROM), enhanced function and reduced impairment. Pendular and pulley exercises focus on pain relief and improving basic shoulder mobility, with pendular being passive and pulley exercises being active-assisted [35]. In contrast, PNF exercises emphasise neuromuscular control, scapular stability and functional movement. Research shows PNF is superior in enhancing range of motion, reducing pain and improving overall functional performance, making it a more comprehensive rehabilitation option [28]. Assessing scapular stiffness following long-term treatment may yield different outcomes, as studies have demonstrated that the use of an exercise program during long-term treatment has resulted in improved shoulder discomfort and function. Since there were no participants who dropped out of the trial, there was no need to conduct an intention-to-treat analysis.

A significant constraint of this investigation was that the trial therapists were unable to be blinded to the treatment allocation. The researcher attempted to mitigate the impact of unbinding by providing training to the trial therapists, blinding the assessor and patient about the trial allocation. Treatment was provided in two units to prevent trial contamination. As samples were collected only from CRP, Savar, Dhaka, Bangladesh, they could not represent the wider adhesive capsulitis population and the study lacks in generalise ability of results to the wider population. There may be another possible limitation that the training dosage or number of repetitions was not sufficient and more frequent training sessions may be required. The statistical analysis was confined to non-parametric analysis and no confidence interval of mean improvement was calculated. The study did not offer any follow-up for participants which was an essential component to find out the effectiveness of treatment for a longer period. Yet, this is the single trial of PNF in Bangladesh with a standard protocol, trial registration following guidelines of the EQUATOR network. So the study will add a new dimension to the clinical practice of AC in Bangladesh.

Conclusions

Proprioceptive neuromuscular facilitation technique (PNF) has greater clinical effect than conventional standard physiotherapy as exercise, stretching and electrotherapy in 6 weeks on pain remission, ROM improvement and remission of disability in shoulder adhesive capsulitis (AC). However, the results are promising and require further multicentre and multistage trials with external generalisation.

Abbreviations

ADL	Activities of daily living
CRP	Centre for the rehabilitation of the paralysed
NCS	Nerve conduction study
NPRS	Numeric pain rating scale
PASS	Power analysis & sample size
SPADI	Shoulder pain and disability index

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Authors' contributions

AHK wrote the main manuscript; KMAH made the necessary corrections; MFK, MZH, SJ and MSHB prepared the supplementary files and ER supervised the project. All authors reviewed and approved the manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Authors received the ethical permission to conduct the trial from the Institutional Review Board (IRB), Bangladesh Health Professions Institute (BHPI), Centre for the Rehabilitation of the Paralysed (CRP), Savar, Dhaka 1343, Bangladesh (CRP-BHPI/IRB/08/2021/676). This trial is also listed in the Australian New Zealand Clinical Trial Registry (ACTRN) (ACTRN12621001299897) which is a primary clinical trial registry of the World Health Organization (WHO). The Helsinki Declaration was followed during the study, and we obtained informed consent from all subjects and their legal guardians.

Consent for publication
The participants were provided with informed consent before publishing any information.

Competing interests
The authors declare no competing interests.

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