

Effectiveness of Proprioceptive Neuromuscular Facilitation and Muscle Energy Technique for Shoulder Instability in Swimmers

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Abstract:

➤ Introduction:

Shoulder instability is a common and debilitating condition in competitive swimmers, primarily caused by repetitive overhead motions that lead to muscular imbalances and decreased performance. Proprioceptive Neuromuscular Facilitation (PNF) and Muscle Energy Technique (MET) are established manual therapies for restoring joint function. However, there is a significant gap in research directly comparing their effectiveness within the elite swimming population, creating a need for evidence-based guidance on optimal rehabilitation strategies.

➤ Methods:

A comparative study was conducted over four weeks with 50 swimmers (aged 10–25 years). Participants were randomly allocated to two groups: Group A (n=25) received PNF, and Group B (n=25) received MET. Outcomes—shoulder ROM (goniometry), strength (M-AST), stability (OSIS), and swim times (25m, 50m, 450m)—were analysed using t-tests ($p < 0.05$).

➤ Results:

Following the 4-week intervention, both groups demonstrated improvement in shoulder range of motion, muscle strength, functional stability, and swimming performance. However, Group B (Muscle Energy Technique) showed significantly greater improvements across most parameters. In terms of internal rotation, Group B improved by 6.96° ($p = 0.0184$), while Group A (Proprioceptive Neuromuscular Facilitation) showed a lesser and non-significant gain of 3.48° ($p = 0.2192$). Similarly, external rotation increased by 6.48° in Group B ($p = 0.0379$) compared to 3.84° in Group A ($p = 0.2331$). Muscle strength, assessed via the Modified Athletic Shoulder Test at 90° , 135° , and 180° abduction angles, improved significantly more in Group B, with mean gains of 2.28 kg, 2.20 kg, and 1.92 kg respectively ($p < 0.01$ for all), whereas Group A showed modest, statistically insignificant changes. Functional stability, measured by the Oxford Shoulder Instability Score, improved by 3.40 points in Group B ($p = 0.0126$) versus 2.12 points in Group A ($p = 0.1323$). Regarding swimming performance, both groups achieved statistically significant improvements across 25m, 50m, and 450m trials. Group A demonstrated slightly better gains in the 25m sprint, while Group B showed superior results in the 50m and 450m distances, although the difference between the groups was minimal.

➤ Conclusion:

Both PNF and MET are effective in improving shoulder function and swim performance in swimmers with shoulder instability. However, MET showed significantly greater improvements in ROM, strength, and shoulder stability, making it a more effective intervention for long-term rehabilitation. PNF may be more beneficial for enhancing short-distance swim speed due to its functional movement emphasis.

Keywords: Proprioceptive Neuromuscular Facilitation, Muscle Energy Technique, Shoulder Instability, Swimmers, Rehabilitation, Sports Physiotherapy.

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I. INTRODUCTION

The shoulder complex, intricately is a designed combination of four joints (Sternoclavicular joint, Acromioclavicular joint, Glenohumeral joint, and Scapulothoracic joint), among these scapulothoracic joint is considered to be a functional joint while others are deemed true anatomical joint. Out of all the joints in the shoulder complex, the glenohumeral joint is particularly notable for its extensive range of motion, allowing for activities like reaching, throwing, and lifting.^{1,2} Shoulder instability, refers to the patient experiencing symptoms of having a shoulder joint that is unstable in certain positions and is usually accompanied by increased laxity in that direction² or a symptomatic abnormal motion of glenohumeral joint, which can present as pain or a sense of displacement (varied from microinstability to subluxation and ultimately dislocation) is a relatively common musculoskeletal problem in swimmers.^{1,2} Shoulder instability can be categorized by onset, direction, and degree. Based on onset, it can be traumatic, atraumatic, or due to overuse. Directionally, it is classified as anterior, posterior, or multidirectional. The Stanmore Classification according to Jaggi & Lambert, 2010 provides a framework about the degree of shoulder instability:³

Polar Type I – Structural Instability

Polar Type II – Atraumatic Instability

Polar Type III – Neurological Dysfunctional or Muscle patterning

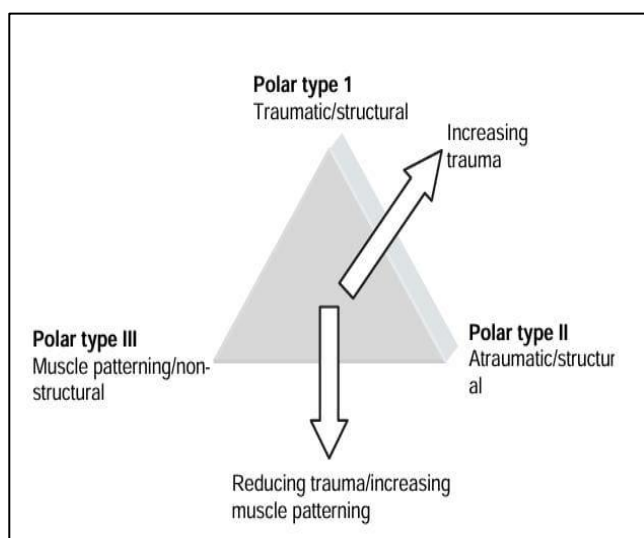


Fig 1 Stanmore Classification of Shoulder Instability³

“Swimmer’s shoulder” a common and debilitating condition as described by Kennedy and Hawkins in 1974 consists in discomfort after swimming activities in first step, which may progress to shoulder pain during and after the training. It is reported that swimmer’s pain and instability is

generally seen between 40% to 91%.⁴ “Swimmer’s shoulder” encompasses a variety of co-existing pathologies, including impingement syndrome, shoulder instability, scapular dyskinesis, rotator cuff tendinitis, bursitis, and labral damage. Recent studies suggests that glenohumeral instability and impingement possibly represents a different stage of the same condition.⁵ The instability often arises from several factors: improper training techniques, capsular tightness from repetitive overhead movements, glenohumeral laxity, muscular imbalances, and altered muscle activation patterns. Orientation of the muscle is a key in defining force where a sum of all the vectors constitutes a net reaction force. The forces exerted by the deltoid muscle fibres specially, posterior and middle portions with rotator cuff muscle which limits the humeral head translations. Any misalignment of these muscles increases the chances of instability.⁶ Normally glenohumeral laxity are quite advantageous for swimmers but up to a threshold point allowing for a greater stroke length with sufficient speed and efficiency but exceeding it results in humeral translation and compromise in stability which gives rise to muscle imbalance and further complications. Range of motion and instability is considered to be correlated especially the shoulder internal and external rotation which fluctuates the tensile stress and thus restricting on the joint and soft tissue structures.^{4,7,8} The primary goal of treating shoulder instability in swimmers is to restore range of motion and strength while easing pain. Techniques such as Proprioceptive Neuromuscular Facilitation and Muscle Energy Techniques can be particularly effective in this context as Proprioceptive Neuromuscular Facilitation can enhance flexibility and strengthen the muscles, while Muscle Energy Techniques focuses on improving range of motion and correcting muscle imbalances. Together, these approaches can help swimmers regain optimal shoulder function and reduce the risk of further injury.^{9,10,11}

In swimmers, who are highly prone to shoulder instability due to repetitive overhead motion and high demands on the glenohumeral joint, PNF offers a structured means of improving mobility, dynamic stability, and motor coordination. By incorporating diagonal and spiral movement patterns, PNF mimics the functional demands of swimming strokes, particularly freestyle and butterfly, which require multi-planar control and shoulder joint integrity.^{12,13} The primary aim of PNF in this context is to facilitate joint stability and neuromuscular re-education by stimulating proprioceptors within muscles and joints, enhancing the activation of stabilizing musculature such as the rotator cuff and scapular stabilizers.

PNF techniques such as contract-relax (CR), hold-relax (HR), alternating isometrics (AI), and rhythmic stabilization (RS) are particularly effective in addressing the deficits associated with shoulder instability. For instance, contract-relax utilizes the principle of autogenic inhibition, allowing tight musculature—such as the internal rotators or posterior capsule—to relax and lengthen after isometric contraction.

Meanwhile, alternating isometrics and rhythmic stabilization enhance joint stability by promoting co-contraction of agonist and antagonist muscle groups, which is essential in maintaining shoulder stability during rapid, repetitive movements like swim strokes.^{14,15} Therefore, incorporating PNF into shoulder rehabilitation for swimmers not only restores mechanical alignment but also re-trains the proprioceptive system for long-term joint integrity and performance enhancement.

Muscle Energy Technique (MET) is a form of osteopathic manipulative therapy where the patient actively contracts specific muscles from a controlled position against a precisely directed resistance applied by the therapist. In swimmers with shoulder instability, MET can be strategically used to lengthen tight internal rotators (e.g., pectoralis major, subscapularis) and strengthen underactive external rotators (e.g., infraspinatus, teres minor), thereby rebalancing the forces acting on the shoulder joint.^{11,16} The effectiveness of MET lies in its underlying neurophysiological principles. When a muscle performs an isometric contraction, Golgi tendon organs (GTOs) are activated, triggering autogenic inhibition, which reduces motor neuron excitability and allows the muscle to relax and lengthen post-contraction. This mechanism is particularly useful in lengthening the shortened posterior shoulder structures often found in swimmers. Post-isometric relaxation technique enables improved range of motion while reinforcing neuromuscular control, repeated over several sessions, helps restore symmetrical movement patterns and enhance joint centration during the catch and pull phases of swimming for swimmers with anterior shoulder joint instability and tight internal rotators.^{16, 13}

II. METHOD

➤ Design

This study was designed as a comparative experimental trial with two parallel intervention groups. The duration of the intervention was four weeks, during which participants underwent structured physiotherapy sessions three times per week. Random allocation was performed using a simple random sampling method to ensure equal distribution of participants into the two groups. Blinding of assessors was maintained to minimize bias during outcome measurement. Data analysis was conducted using both within-group (paired t-tests) and between-group (unpaired t-tests) comparisons, with a significance threshold set at $p < 0.05$. The study adhered to the principles of the Declaration of Helsinki, and ethical approval was obtained from the institutional ethics committee.

➤ Participants

A total of 50 competitive swimmers aged between 10 and 25 years with clinically diagnosed shoulder instability

were recruited for the study. Inclusion criteria required participants to be active swimmers with at least two years of regular training experience, presenting with signs of shoulder instability confirmed by clinical tests such as the apprehension test. Exclusion criteria included any history of recent fractures, systemic illness, prior shoulder surgery, neurological disorders, or current participation in other rehabilitation programs. Participants were randomly divided into two groups of 25 each: Group A received Proprioceptive Neuromuscular Facilitation (PNF) techniques, while Group B received Muscle Energy Technique (MET). All participants and guardians (where applicable) provided informed written consent before inclusion in the trial.

➤ Inclusion Criteria

Participants included will be:

- Participants within the age group of 10 years to 25 years.
- Both Male and Female participants.
- Patients with symptoms of shoulder instability.
- All stroking technique in swimmers.
- Symptoms of Impingement Syndrome

➤ Exclusion Criteria

Participants excluded will be:

- Surgeries and arthroscopy of shoulder within 3 months.
- Fractures within 3 months
- Neurological deficits
- Cervical pathology
- Cardiac deficits
- Respiratory impairments
- Rotator cuff strain (Grade I, II, III)

III. PROCEDURE

➤ Group A: Proprioceptive Neuromuscular Facilitation (PNF)

Participants allocated to Group A, received PNF techniques specifically designed for the shoulder joint complex. The intervention emphasized diagonal upper limb patterns (D1 flexion-extension, D2 flexion-extension) and scapular patterns (anterior elevation-posterior depression, posterior elevation-anterior depression). Techniques incorporated contract-relax for 1st – 2nd weeks to enhance range of motion and alternating isometrics for 3rd – 4th week to improve shoulder stability and neuromuscular control. Each session included 3–5 repetitions of each pattern, with 10–15 second holds, interspersed with rest periods. Treatment was progressed by increasing resistance and movement complexity according to participant tolerance. Sessions lasted approximately 30 minutes, three times per week, for 4 weeks. Table 1, represents Protocol for PNF.

Table 1 Representing Protocol for PNF (Group A)

WEEKS	TECHNIQUE USED	PATTERNS	PATIENT POSITION	DOSAGE (repetitions* sets)
Week 1 - 2	Contract - Relax	D1 Flexion	Supine lying	10 Repetitions * 3 sets/ session
		D1 Extension	Supine lying	10 Repetitions * 3 sets/ session
		D2 Flexion	Supine lying	10 Repetitions * 3 sets/ session

Week 3 - 4	Alternating Isometrics	D2 Extension	Supine lying	10 Repetitions * 3 sets/ session
		Scapular Anterior Elevation	Side lying	10 Repetitions * 3 sets/ session
		Scapular Posterior Depression	Side lying	10 Repetitions * 3 sets/ session
		Scapular Anterior Depression	Side lying	10 Repetitions * 3 sets/ session
		Scapular Posterior Elevation	Side lying	10 Repetitions * 3 sets/ session
		D1 Flexion	Supine lying	5 Repetitions * 10 seconds hold each in 3 ranges * 3 sets/ session
		D1 Extension	Supine lying	5 Repetitions * 10 seconds hold each in 3 ranges* 3 sets/ session
		D2 Flexion	Supine lying	5 Repetitions * 10 seconds hold each in 3 ranges* 3 sets/ session
		D2 Extension	Supine lying	5 Repetitions * 10 seconds hold each in 3 ranges * 3 sets/ session
		Scapular Anterior Elevation	Side lying	15 Repetitions * 3 sets/ session
		Scapular Posterior Depression	Side lying	15 Repetitions * 3 sets/ session
		Scapular Anterior Depression	Side lying	15 Repetitions * 3 sets/ session
		Scapular Posterior Elevation	Side lying	15 Repetitions * 3 sets/ session

➤ *Group B: Muscle Energy Technique (MET)*

Participants in Group B underwent MET interventions targeting the major shoulder movements. Post-isometric relaxation (PIR) was applied for shoulder flexion, extension, abduction, medial rotation, and lateral rotation. For each movement restriction, participants performed a gentle isometric contraction (approximately 25% of maximal effort for 1st – 2nd week then increasing to 50% for 3rd – 4th week) against the therapist's resistance for 7–10 seconds, followed

by relaxation and passive movement into the new available range. This cycle was repeated 3–5 times for each restricted movement. MET was applied bilaterally when needed but focused primarily on the affected shoulder. Progression was achieved by gradually increasing contraction intensity and range of motion. Sessions lasted approximately 30 minutes, three times per week, for 4 weeks. Table 2, represents Protocol for MET.

Table 2 Representing Protocol for MET (Group B)

WEEKS	TECHNIQUES USED	MOVEMENTS	PATIENT POSITION	EFFORTS APPLIED IN % BY THE PATIENT	DOSAGE
Week 1 -2	Post – isometric relaxation	Shoulder Flexion	Supine, shoulder and elbow flexed	25% effort, 7 – 10 sec, inhale and exhale cycle	5 Repetitions * 3 sets/ session
		Shoulder Extension	Prone	25% effort, 7 – 10 sec, inhale and exhale cycle	5 Repetitions * 3 sets/ session
		Shoulder Abduction	Supine	25% effort, 7 – 10 sec, inhale and exhale cycle	5 Repetitions * 3 sets/ session
		Shoulder Lateral Rotation	Supine, shoulder 90° abduction, elbow 90° flexed	25% effort, 7 – 10 sec, inhale and exhale cycle	5 Repetitions * 3 sets/ session
		Shoulder Medial Rotation	Supine at table edge, shoulder abducted 90°, elbow flexed	25% effort, 7 – 10 sec, inhale and exhale cycle	5 Repetitions * 3 sets/ session
Week 3 - 4	Post – isometric Relaxation	Shoulder Flexion	Supine lying, shoulder & elbow flexed	50% max effort for 20 sec, inhale before & exhale after	5 Repetitions * 3 sets/ session
		Shoulder Extension	Prone	50% max effort for 20 sec, inhale before & exhale after	5 Repetitions * 3 sets/ session
		Shoulder Abduction	Supine	50% max effort for 20 sec, inhale before & exhale after	5 Repetitions * 3 sets/ session
		Shoulder Lateral Rotation	Supine, shoulder abducted 90°, elbow flexed 90°	50% max effort for 20 sec, inhale before & exhale after	5 Repetitions * 3 sets/ session

		Shoulder Medial Rotation	Supine at table edge, shoulder abducted 90°, elbow flexed	50% max effort for 20 sec, inhale before & exhale after	5 Repetitions * 3 sets/ session
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IV. OUTCOME MEASURES

➤ *Shoulder Range of Motion (ROM):*

Active and passive ROM of the shoulder internal rotation (IR) and external rotation (ER) was measured using a standard universal goniometer. Participants were positioned supine with the shoulder abducted to 90° and elbow flexed to 90°. The axis was aligned with the olecranon process, the stationary arm perpendicular to the floor, and the movable arm aligned with the ulna. Three readings were taken for both IR and ER, and the average value was used for analysis.

➤ *Modified Athletic Shoulder (M-AST)*

Test¹⁷ is a field-based assessment tool designed to evaluate shoulder strength and control, particularly in overhead and contact athletes. The test involves the athlete performing maximal isometric contractions in prone position at various arm angles (180°, 135°, and 90° abduction) by handheld dynamometer, simulating sport-specific positions to assess the functional capacity of the shoulder stabilizers.

➤ *Functional Shoulder Stability:*

Evaluated with the Oxford Shoulder Instability Score (OSIS),¹⁸ a 12-item questionnaire assessing pain, instability, and activity limitations. Scores range from 12 to 60, with lower values indicating greater instability.

➤ *Swimming Performance:*

Time taken for 25m (sprint), 50m (short-distance), and 450m (endurance) swims were recorded under standardized pool conditions. Each distance was tested twice, and the fastest time was included for analysis.

V. DATA ANALYSIS

A priori power analysis was conducted to determine the minimum sample size required for the study. Assuming a moderate effect size (Cohen's $d = 0.5$), a power of 0.80, and an alpha level of 0.05, the analysis indicated that a minimum of 23 participants per group was required. To account for possible dropouts, 25 participants were recruited in each group, yielding a total of 50 swimmers.

Goniometric readings for internal and external rotation were recorded in degrees, and three trials were averaged to obtain a single representative score for each participant. Strength data obtained from the Modified Athletic Shoulder Test were converted into kilograms, and mean values were calculated from three repetitions at each abduction angle (90°, 135°, and 180°). For swimming performance, times from two trials for each distance (25m, 50m, 450m) were recorded, and the fastest trial was considered for analysis. Oxford Shoulder Instability Scores were summed according to the standardized scoring system.

The research questions were addressed through within-group comparisons of pre- and post-intervention outcomes, which tested whether each intervention produced significant improvements over time, and between-group comparisons, which determined whether MET or PNF was more effective. Statistical tests included paired comparisons for within-group changes and independent comparisons for between-group differences. A threshold of $p < 0.05$ was used to determine statistical significance, and 95% confidence intervals were calculated to assess the precision of observed effects.

➤ *Descriptive Characteristics:*

A total of 25 swimmers were included in Group A (PNF), comprising 11 females (44%) and 14 males (56%). Participants were aged 15–23 years, with the highest representation in the 16-year (20%) and 19-year (16%) age groups. Freestyle was the most commonly preferred stroke ($n = 14$, 56%), followed by butterfly ($n = 5$, 20%), while backstroke and breaststroke were each chosen by 3 participants (12% each).

Similarly, 25 swimmers were enrolled in Group B (MET), including 8 females (32%) and 17 males (68%). The age range was 15–25 years, with the majority between 15 and 21 years. Three participants each were aged 15, 17, 20, and 21 years, while fewer were observed in the older age brackets, with only one participant each at 24 and 25 years. The mean age of the group was approximately 19.4 years. Stroke preference analysis revealed that freestyle was the most common discipline (43%), followed by butterfly (26%), backstroke (15%), and breaststroke (12%).

➤ *Data*

• *Within Group Analysis:*

The within-group analysis revealed distinct differences in the effectiveness of PNF and MET interventions on shoulder function and swimming performance.

• *Range of Motion (ROM):*

For internal rotation, Group A (PNF) showed a mean improvement of 3.48° (5.04%), which was not statistically significant ($p = 0.2192$, $d = 0.35$). In contrast, Group B (MET) demonstrated a significantly greater improvement of 6.96° (10.29%) ($p = 0.0184$, $d = 0.69$), indicating a medium to large effect. Similarly, for external rotation, PNF achieved a non-significant gain of 3.84° (5.43%) ($p = 0.2331$, $d = 0.34$), while MET produced a statistically significant increase of 6.48° (9.32%) ($p = 0.0379$, $d = 0.60$), reflecting a moderate effect. These results suggest that MET was superior to PNF in improving ROM, particularly in rotational movements.

• *Muscle Strength (M-AST):*

At 90° abduction, PNF improved strength by 0.94 kg (10.68%), which was not significant ($p = 0.1289$, $d = 0.44$). Conversely, MET showed a significant gain of 2.28 kg

(19.79%) ($p = 0.0029$, $d = 0.89$), indicating a large effect. At 135° abduction, PNF increased by 0.70 kg (6.36%) ($p = 0.2961$, $d = 0.30$), while MET improved significantly by 2.20 kg (18.31%) ($p = 0.00063$, $d = 1.03$), representing a very large effect. At 180° abduction, PNF gains of 0.80 kg (7.25%) were not significant ($p = 0.2366$, $d = 0.34$), whereas MET improvements of 1.92 kg (16.33%) were statistically significant ($p = 0.0099$, $d = 0.76$). Overall, MET consistently outperformed PNF in muscle strength across all abduction angles, with large to very large effect sizes.

- **Functional Stability (OSIS):**

PNF produced a non-significant increase of 2.12 points (7.15%) ($p = 0.1323$, $d = 0.43$). MET, however, achieved a significant gain of 3.40 points (10.73%) ($p = 0.0126$, $d = 0.73$), suggesting a moderate to large effect. This highlights the greater efficacy of MET in enhancing functional shoulder stability.

- **Swimming Performance:**

For 25m sprint performance, both interventions were highly effective. PNF reduced swim time by 3.14 seconds (–20.26%) with a very large effect ($p < 0.0001$, $d = 2.01$), while MET reduced time by 2.95 seconds (–19.26%) ($p < 0.0001$, $d = 1.66$). PNF demonstrated a slightly greater improvement in short-distance sprinting. At 50m, PNF improved by 4.58 seconds (–14.98%) ($p < 0.0001$, $d = 1.27$), while MET improved by 4.24 seconds (–14.02%) ($p < 0.001$, $d = 1.07$); both were highly significant with large effects, though PNF again showed slightly superior gains. For 450m long-distance performance, PNF improved by 0.76 minutes (–13.69%) ($p < 0.0001$, $d = 1.68$), and MET improved by 0.78 minutes (–13.91%) ($p < 0.0001$, $d = 1.67$). Both interventions were equally effective, with nearly identical large effect sizes. Table 3, represents the Within-Group Comparison of Range of Motion, Strength, Stability, and Swimming Performance following PNF and MET Interventions.

Table 3 Within-Group Comparison of Range of Motion, Strength, Stability, and Swimming Performance following PNF and MET Interventions

Outcome Measure	Group	Mean Diff.	% Change	Effect Size (d)	p-value
Internal Rotation (°)	PNF	3.48	5.04%	0.35	0.2192
	MET	6.96	10.29%	0.69	0.0184
External Rotation (°)	PNF	3.84	5.43%	0.34	0.2331
	MET	6.48	9.32%	0.60	0.0379
M-AST (90°)	PNF	0.94 kg	10.68%	0.44	0.1289
	MET	2.28 kg	19.79%	0.89	0.0029
M-AST (135°)	PNF	0.70 kg	6.36%	0.30	0.2961
	MET	2.20 kg	18.31%	1.03	0.00063
M-AST (180°)	PNF	0.80 kg	7.25%	0.34	0.2366
	MET	1.92 kg	16.33%	0.76	0.0099
OSIS Score	PNF	2.12	7.15%	0.43	0.1323
	MET	3.40	10.73%	0.73	0.0126
25m Swim Time	PNF	–3.14 s	–20.26%	2.01	9.36×10^{-9}
	MET	–2.95 s	–19.26%	1.66	1.89×10^{-7}
50m Swim Time	PNF	–4.58 s	–14.98%	1.27	0.00004
	MET	–4.24 s	–14.02%	1.07	0.00045
450m Swim Time	PNF	–0.76 min	–13.69%	1.68	3.37×10^{-7}
	MET	–0.78 min	–13.91%	1.67	3.54×10^{-7}

- **Between Group Analysis:**

The between-group comparison (PNF vs. MET) demonstrated consistent and statistically significant differences across all measured outcomes, favoring Group B (MET) in most parameters, except for sprint swimming times where Group A (PNF) showed slightly better performance at shorter distances.

- **Range of Motion**

For internal rotation, Group B exhibited a greater mean improvement ($6.96^\circ \pm 4.31$) compared to Group A ($3.48^\circ \pm 1.64$). The between-group analysis revealed a significant difference ($t = -3.78$, $p = 0.0004$), indicating superior gains in shoulder internal rotation with MET. Similarly, for external rotation, Group B achieved a larger mean gain ($6.48^\circ \pm 3.08$) compared to Group A ($3.84^\circ \pm 1.55$), with the difference also statistically significant ($t = -3.83$, $p = 0.0004$). These findings suggest that MET was significantly more effective in enhancing shoulder joint rotational flexibility.

- **Muscle Strength (M-AST):**

At all abduction angles (90°, 135°, and 180°), Group B demonstrated significantly greater improvements in muscle strength: At 90°, Group B improved by 2.28 ± 0.66 kg compared to 0.94 ± 0.44 kg in Group A ($t = -8.42$, $p < 0.0001$). At 135°, Group B improved by 2.20 ± 0.60 kg, whereas Group A showed only 0.70 ± 0.32 kg, with a highly significant difference ($t = -11.08$, $p < 0.0001$) and at 180°, Group B again outperformed Group A, with mean gains of 1.92 ± 0.66 kg vs. 0.80 ± 0.38 kg ($t = -7.37$, $p < 0.0001$).

The effect sizes (all very large, Cohen's $d > 0.8$) further reinforce the clinical superiority of MET in improving shoulder muscle strength at multiple ranges.

- **Functional Stability (OSIS Score)**

Group B recorded a higher mean improvement in the Oxford Shoulder Instability Score (3.40 ± 0.76) compared to Group A (2.12 ± 0.73). The between-group analysis showed

a highly significant difference ($t = -6.08$, $p < 0.0001$), indicating greater functional stabilization of the shoulder joint with MET.

Both groups showed significant improvements in swim times, but with differences in distance-specific performance, in 25m, Group A showed slightly less improvement (-1.60 ± 0.64 s) than Group B (-2.95 ± 1.08 s), the difference between groups was highly significant ($t = -5.34$, $p < 0.0001$), favoring Group B. At 50m, the MET group again showed markedly

greater gains (-4.24 ± 1.14 s) compared to PNF (-1.79 ± 0.64 s), with the difference strongly significant ($t = -9.37$, $p < 0.0001$). For endurance swimming (450m), MET produced a mean improvement of -0.78 ± 0.34 min, which was significantly greater than the PNF group's -0.30 ± 0.21 min ($t = -6.01$, $p < 0.0001$).

These results indicate that MET had a stronger impact on mid- to long-distance swimming performance, whereas PNF offered relatively less benefit.

Table 4 Between-Group Comparison of Shoulder Range of Motion, Muscle Strength, Functional Stability, and Swimming Performance Outcomes in PNF and MET Interventions

Outcome Measure	Group A (PNF) Mean $\pm$ SD	Group B (MET) Mean $\pm$ SD	Mean Difference (A vs. B)	t-value	p-value
Internal Rotation ($^{\circ}$)	3.48 ± 1.64	6.96 ± 4.31	-3.48	-3.78	0.0004
External Rotation ($^{\circ}$)	3.84 ± 1.55	6.48 ± 3.08	-2.64	-3.83	0.0004
M-AST (90°)	0.94 ± 0.44	2.28 ± 0.66	-1.34	-8.42	1.47×10^{-10}
M-AST (135°)	0.70 ± 0.32	2.20 ± 0.60	-1.50	-11.08	2.62×10^{-13}
M-AST (180°)	0.80 ± 0.38	1.92 ± 0.66	-1.12	-7.37	6.60×10^{-9}
OSIS Score	2.12 ± 0.73	3.40 ± 0.76	-1.28	-6.08	1.93×10^{-7}
25m Swim Time (s)	-1.60 ± 0.64	-2.95 ± 1.08	+1.35	-5.34	4.25×10^{-6}
50m Swim Time (s)	-1.79 ± 0.64	-4.24 ± 1.14	+2.45	-9.37	2.05×10^{-12}

VI. RESULTS

A total of 50 swimmers with shoulder instability were divided equally into two groups: Group A (PNF) and Group B (MET). Both groups completed a 4-week intervention, and outcome measures were analysed before and after treatment.

➤ Range of Motion (ROM):

- Internal Rotation: Group A improved by 3.48° (5.04%), which was not statistically significant ($p = 0.2192$), while Group B improved by 6.96° (10.29%) with a statistically significant change ($p = 0.0184$). Between-group analysis revealed that Group B achieved significantly greater gains than Group A ($p = 0.0004$).
- External Rotation: Group A showed a mean gain of 3.84° (5.43%, $p = 0.2331$), while Group B improved by 6.48° (9.32%, $p = 0.0379$). Between-group analysis again demonstrated that MET was superior ($p = 0.0004$).

➤ Muscle Strength (M-AST Scores):

At all abduction angles, Group B demonstrated significantly larger improvements compared to Group A.

- At 90° , Group A improved by 0.94 kg (10.68%, $p = 0.128$) versus Group B's 2.28 kg (19.79%, $p = 0.0029$).
- At 135° , Group A improved by 0.70 kg (6.36%, $p = 0.296$), while Group B gained 2.20 kg (18.31%, $p < 0.001$).
- At 180° , Group A improved by 0.80 kg (7.25%, $p = 0.236$), while Group B showed a significant gain of 1.92 kg (16.33%, $p = 0.0098$).
- Between-group comparisons at all angles confirmed highly significant differences in favor of Group B ($p < 0.001$).

➤ Functional Stability (OSIS Scores):

Group A improved by 2.12 points (7.15%, $p = 0.132$, non-significant), while Group B improved by 3.40 points (10.73%, $p = 0.0126$). Between-group comparison revealed statistically significant superiority of MET over PNF ($p < 0.01$).

➤ Swimming Performance:

- 25m Sprint: Both groups improved significantly. Group A reduced time by 3.14 sec (20.26%, $p < 0.001$), slightly more than Group B's 2.95 sec (19.26%, $p < 0.001$). PNF showed marginal superiority in sprint performance.
- 50m Swim: Group A improved by 4.58 sec (14.98%, $p < 0.001$), while Group B improved by 4.23 sec (14.02%, $p < 0.001$). Both were effective, but Group A showed slightly better results.
- 450m Distance: Both groups improved almost equally. Group A improved by 0.76 min (13.69%, $p < 0.001$) and Group B by 0.78 min (13.91%, $p < 0.001$), with negligible difference between them.

VII. DISCUSSION

The present study aimed to compare the effects of Proprioceptive Neuromuscular Facilitation (PNF) and Muscle Energy Technique (MET) on shoulder instability in swimmers aged 10–25 years. Both interventions were implemented over a four-week period, and the outcomes were assessed based on improvements in shoulder range of motion (ROM), muscular strength, functional stability, and swimming performance. The results indicated that although both PNF and MET led to measurable improvements, MET produced significantly greater gains in ROM, strength, and stability, while PNF showed a slight advantage in short-distance swimming performance.

The MET group demonstrated a significant gain in internal rotation of 6.96° ($p = 0.0184$), whereas PNF group showed only a 3.48° increase ($p = 0.2192$). Similarly, external rotation improved by 6.48° in Group B ($p = 0.0379$) compared to 3.84° in Group A ($p = 0.2331$), with highly significant between-group differences ($p = 0.0004$). These results support previous findings by Reed et al., who reported that MET effectively reduces posterior shoulder tightness and improves rotation in overhead athletes.¹⁹ MET likely produces these improvements through post-isometric relaxation, which facilitates greater muscle elongation and capsular stretch.

Additionally, the MET group's superior gains in Muscle strength evaluated through the Modified Athletic Shoulder Test (MAST) also favored MET. For instance, at 90° abduction, Group B improved by 2.28 kg ($p = 0.0029$) compared to 0.94 kg in Group A ($p = 0.1288$). The trend persisted across 135° and 180° abduction. The trend persisted across 135° and 180° abduction. These results align with Ganesh et al., who demonstrated that MET effectively strengthened scapular muscles and improved range of motion in young swimmers.²⁰

Functional stability, measured by the Oxford Shoulder Instability Score (OSIS), improved significantly more in the MET group (3.40 points) compared to the PNF group (2.12 points), with a highly significant between-group difference ($p < 0.00001$). This improvement aligns with Rabbani and Shetty's findings that MET reduces shoulder tightness and improves dynamic shoulder stability in overhead athletes.²¹ Similar results were seen in a recent study it was observed ROM was improved and pain was reduced in patients with adhesive capsulitis treated with MET over conventional therapy.²² These outcomes emphasize MET's effectiveness in addressing underlying mechanical restrictions and enhancing neuromuscular function.

Interestingly, PNF showed slightly better improvements in short-distance swimming times, particularly in the 25 m sprint. This is likely due to PNF's emphasis on functional movement patterns and proprioceptive feedback, which are essential in dynamic sports like swimming. As noted by Li et al., PNF enhances shoulder flexibility and improves performance in freestyle swimmers by optimizing neuromuscular coordination and muscle activation patterns.²³ The ability of PNF to influence motor control may explain the faster swim times, despite lesser improvements in raw strength or ROM.

Although some studies, such as Tamjeed et al.²⁴, reported better results with PNF than MET in clinical populations (e.g., adhesive capsulitis), this contrast may stem from the athletic vs. non-athletic nature of the study

populations. In active individuals like swimmers, MET may provide more structural benefit, while PNF might be more beneficial for those focusing on mobility restoration without performance demands. Farquharson also emphasized that while both PNF and MET aim to improve muscle flexibility, MET is more targeted toward structural correction, while PNF focuses on enhancing coordinated motor patterns.²⁵

These findings support a phase-based rehabilitation approach where MET can be utilized in the early to mid-phase of rehab to correct mechanical dysfunctions, while PNF may be more useful in the return-to-sport or performance enhancement phase. The complementary nature of both techniques opens the door for future studies investigating combined or sequential application protocols.

In summary, this study adds to the growing body of literature supporting MET as a highly effective intervention for improving shoulder function in swimmers. While PNF remains beneficial for enhancing performance, particularly in explosive tasks, MET is superior in addressing structural limitations and functional deficits associated with shoulder instability.

VIII. CONCLUSION

This comparative study demonstrated that while both Proprioceptive Neuromuscular Facilitation (PNF) and Muscle Energy Technique (MET) are effective in the rehabilitation of swimmers with shoulder instability, MET provided statistically and clinically greater improvements in range of motion, shoulder strength, and functional joint stability. These findings are consistent with multiple previous studies that support MET's role in enhancing structural parameters and muscle balance. Conversely, PNF showed a slightly better effect on short-distance swimming performance, likely due to its emphasis on neuromuscular control, proprioception, and movement coordination. This aligns with other research indicating PNF's contribution to athletic skill performance, especially in tasks requiring explosive or well-coordinated shoulder actions.

The data suggest that MET should be prioritized when addressing capsular stiffness, muscular imbalances, and joint dysfunction, especially in athletes needing structural restoration. PNF may serve as an ideal adjunct to improve motor patterns, especially in the early phase of rehabilitation or during sport-specific drills. A combined, phase-specific protocol incorporating both techniques might offer the most comprehensive outcomes for swimmers, enhancing both rehabilitation and performance. Further longitudinal and multicenter studies should assess long-term efficacy and explore the synergistic potential of combining these two methods.

IX. ABBREVIATIONS

Table 5 Abbreviations

PNF	Proprioceptive Neuromuscular Facilitation
MET	Muscle Energy Technique
ROM	Range of Motion
M-AST	Modified Athletic Shoulder Test
OSIS	Oxford Shoulder Instability Score
GTOs	Golgi Tendon Organs

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