The Effect of Diagonal Proprioceptive Neuromuscular Facilitation Movement on Shoulder Joint Range of Motion in Basketball Players with Chronic Shoulder Injuries

Pengaruh Gerakan Diagonal Proprioceptive Neuromuscular Facilitation Terhadap Jangkauan Gerak Sendi Bahu Pada Penderita Cedera Bahu Kronis Atlet Bola Basket

Original Article

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Abstract.

Background Chronic shoulder injury is a common condition among basketball athletes due to repetitive overhead movements and high mechanical demands on the shoulder joint. One of the primary functional consequences of chronic shoulder injury is a reduction in shoulder range of motion (ROM), which may interfere with sport-specific performance and rehabilitation outcomes. Exercise-based interventions that emphasize functional movement patterns are therefore essential to restore optimal shoulder mobility in athletes.

Objectives This study aimed to examine the effect of diagonal proprioceptive neuromuscular facilitation (PNF) exercises on shoulder range of motion in basketball athletes with chronic shoulder injury.

Methods A randomized controlled trial with a pretest–posttest control group design was conducted involving 28 male basketball athletes with chronic shoulder injury. Participants were randomly assigned to a diagonal PNF intervention group (n = 14) or a control group (n = 14). The intervention group performed diagonal PNF exercises (D1 and D2 patterns) three times per week for one week, while the control group continued routine activities without additional intervention. Shoulder ROM, including flexion, extension, abduction, adduction, internal rotation, and external rotation, was measured using a goniometer before and after the intervention. Data were analyzed using paired-sample and independent-sample t-tests with a significance level set at $p < 0.05$.

Results The diagonal PNF intervention group showed significant improvements in shoulder extension, abduction, adduction, internal rotation, and external rotation ($p < 0.05$). No significant improvement was observed in shoulder flexion between groups ($p > 0.05$). Posttest comparisons indicated that the intervention group demonstrated significantly greater ROM gains than the control group in most movement directions.

Conclusion Diagonal proprioceptive neuromuscular facilitation exercises are effective in improving shoulder range of motion in basketball athletes with chronic shoulder injury. These findings support the use of diagonal PNF as a functional and sport-specific rehabilitation strategy to enhance shoulder mobility in athletic populations.

Keywords: proprioceptive neuromuscular facilitation, diagonal movement, shoulder range of motion, chronic shoulder injury, basketball athletes

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INTRODUCTION

Shoulder injuries represent one of the most prevalent musculoskeletal problems in both athletic and general populations due to the high mobility and relatively low structural stability of the glenohumeral joint. Globally, shoulder disorders are frequently associated with repetitive overhead activities, leading to chronic impairments such as reduced joint mobility and functional limitations[1][2][3][4]. Previous epidemiological studies indicate that limitations in shoulder range of motion (ROM) significantly affect upper-limb performance and daily functional activities, particularly in sports requiring repetitive throwing, lifting, and reaching movements [5]. In athletic contexts, compromised shoulder ROM has been linked to altered biomechanics, increased compensatory movements, and elevated risk of recurrent injury [6]. Consequently, restoring optimal shoulder mobility remains a central goal in sports rehabilitation and performance maintenance.

At the national and sport-specific level, basketball athletes represent a population with a high risk of chronic shoulder injury due to repetitive overhead actions such as shooting, passing, rebounding, and defensive contact. Continuous mechanical loading and insufficient recovery may gradually lead to adaptive tissue changes, joint stiffness, and restricted ROM [7][8]. Chronic shoulder injury in athletes is often characterized not by acute trauma but by progressive movement limitation that interferes with sport-specific tasks [9]. Reduced shoulder ROM in basketball athletes has been shown to impair technical execution, decrease training efficiency, and limit return-to-play readiness [10]. Therefore, effective rehabilitation strategies that target joint mobility in this population are critically needed.

Exercise-based rehabilitation is widely recognized as a cornerstone intervention for restoring joint mobility following musculoskeletal injury. Among various exercise therapy approaches, proprioceptive neuromuscular facilitation (PNF) has been extensively applied to improve neuromuscular coordination, flexibility, and functional movement patterns [11]. PNF emphasizes spiral and diagonal movement patterns that closely resemble functional and sport-specific actions, making it particularly relevant for athletic rehabilitation [12]. Through proprioceptive stimulation and neuromuscular facilitation, PNF is believed to enhance muscle activation efficiency and joint mobility more effectively than isolated or linear exercises [13]. Previous studies have reported that PNF interventions can produce meaningful improvements in shoulder ROM across various clinical populations [14].

Specifically, diagonal PNF patterns (D1 and D2) engage multiple muscle groups simultaneously and facilitate coordinated movement across the shoulder complex [15]. These diagonal movements incorporate flexion–extension, abduction–adduction, and rotational components, which are essential for functional shoulder performance in basketball. By integrating neuromuscular control and dynamic joint mobilization, diagonal PNF patterns may provide superior stimulation for improving shoulder ROM compared to conventional stretching or isolated strengthening exercises [16]. Several studies have demonstrated the effectiveness of PNF in improving shoulder mobility; however, most existing evidence is derived from non-athletic populations or mixed clinical samples. As a result, the transferability of these findings to competitive basketball athletes with chronic shoulder injury remains uncertain.

Despite the growing body of literature on PNF, a clear research gap persists regarding its specific effects on shoulder ROM in basketball athletes experiencing chronic shoulder injury. Previous investigations have frequently focused on pain reduction, neurological rehabilitation, or general functional outcomes, with limited emphasis on isolated ROM improvements in athletic populations [17]. Furthermore, studies examining PNF interventions in athletes often lack sport-specific movement considerations or employ heterogeneous injury profiles. Consequently, there is insufficient evidence to conclusively determine whether diagonal PNF exercises effectively enhance shoulder ROM in basketball athletes with chronic injury.

Therefore, this study aims to examine the effect of diagonal proprioceptive neuromuscular facilitation exercises on shoulder range of motion in basketball athletes with chronic shoulder injury. By focusing exclusively on ROM outcomes, this research seeks to provide targeted evidence regarding the effectiveness of diagonal PNF as a rehabilitation strategy for improving shoulder mobility in basketball athletes. The findings of this study are expected to contribute to the development of evidence-based exercise interventions for shoulder rehabilitation, support sport-specific rehabilitation planning, and inform practitioners in sports therapy and athletic conditioning.

METHOD

Study Design

This study employed a randomized controlled trial (RCT) with a pretest–posttest control group design. The experimental approach was selected to examine the causal effect of diagonal proprioceptive neuromuscular facilitation (PNF) exercises on shoulder range of motion (ROM) in basketball athletes with chronic shoulder injury. Participants were randomly assigned to either an intervention group or a control group to minimize selection bias and ensure comparability between groups. The study protocol followed ethical principles for human research and was conducted in accordance with institutional guidelines.

Participants

A total of 28 male basketball athletes diagnosed with chronic shoulder injury participated in this study. Participants were recruited from a competitive basketball club and met the inclusion criteria of having a history of shoulder injury lasting more than three months and experiencing restricted shoulder ROM without acute symptoms. Athletes with a history of shoulder surgery, acute traumatic injury, neurological disorders, or systemic musculoskeletal conditions were excluded. After eligibility screening, participants were randomly allocated into two groups: the diagonal PNF intervention group (n = 14) and the control group (n = 14).

Intervention

The intervention group received diagonal proprioceptive neuromuscular facilitation exercises targeting the shoulder joint. The PNF protocol consisted of diagonal movement patterns D1 and D2, incorporating combined motions of flexion–extension, abduction–adduction, and internal–external rotation. Each intervention session lasted approximately five minutes and was conducted three times per week for one week. During each session, participants performed three sets of diagonal PNF movements, with each set lasting one minute and a rest interval of one minute between sets. All exercises were supervised by a trained therapist to ensure correct execution and consistency of resistance.

The control group did not receive any PNF intervention during the study period and continued their usual training activities without additional shoulder-specific exercise therapy.

Outcome Measures

The primary outcome measure of this study was shoulder range of motion (ROM). Active ROM of the shoulder joint was assessed using a standard universal goniometer. Measurements included shoulder flexion, extension, abduction, adduction, internal rotation, and external rotation. All ROM assessments were conducted twice: prior to the intervention (pretest) and immediately after the intervention period (posttest). To enhance measurement reliability, all assessments were performed by the same examiner using standardized measurement procedures.

Data Collection Procedure

Before data collection, participants were familiarized with the testing procedures. Pretest ROM measurements were recorded for both groups under identical conditions. Following completion of the intervention protocol, posttest ROM measurements were obtained using the same measurement techniques and sequence. Participants were instructed to avoid additional shoulder-specific training or therapeutic interventions during the study period to prevent confounding effects.

Statistical Analysis

Data analysis was performed using statistical software. Descriptive statistics were calculated for all variables and presented as mean and standard deviation. The Shapiro–Wilk test was used to assess data normality. Within-group differences between pretest and posttest ROM values were analyzed using paired-sample t-tests. Between-group differences in posttest ROM values were examined using independent-sample t-tests. Statistical significance was set at $p < 0.05$ for all analyses.

RESULTS AND DISCUSSION

Results

Participant Characteristics

A total of 28 basketball athletes completed the study, with no dropouts reported during the intervention period. Participants were randomly assigned to the diagonal PNF intervention group (n = 14) and the control group (n = 14). Baseline characteristics, including age, height, and body mass, were comparable between groups, indicating homogeneity of participant demographics. No significant differences were observed between groups at baseline for any shoulder range of motion (ROM) variables ($p > 0.05$), suggesting that both groups started from a similar functional condition.

Baseline Shoulder Range of Motion

Pretest measurements demonstrated no statistically significant differences between the intervention and control groups across all assessed shoulder ROM parameters, including flexion, extension, abduction, adduction, internal rotation, and external rotation ($p > 0.05$). These findings confirm that baseline shoulder mobility was comparable between groups prior to the intervention. Normality testing using the Shapiro–Wilk test indicated that all ROM data were normally distributed, permitting the use of parametric statistical analyses.

Tabel 1. Normality Test

Variable			Experiment	Conclusion	Control	Conclusion
ROM	Flexion	*Pre*	0.212	Normal	0.821	Normal
		Post	0,016	Tdk Normal	0.732	Normal
		Difference	0.720	Normal	0.022	Abnormal
	Extension	*Pre*	0.296	Normal	0.218	Normal
		Post	0.311	Normal	0.174	Normal
		Difference	0.346	Normal	0.347	Normal
	Abduction	*Pre*	0.031	Tdk Normal	0.087	Normal
		Post	0.202	Normal	0.048	Abnormal
		Difference	0.088	Normal	0.003	Abnormal
	Adduction	*Pre*	0.178	Normal	0.288	Normal
		Post	0.003	Tdk Normal	0.900	Normal
		Difference	0.696	Normal	0.018	Abnormal
	Internal rotation	*Pre*	0.412	Normal	0.625	Normal
		Post	0.182	Normal	0.603	Normal
		Difference	0.002	Tdk Normal	0.027	Abnormal
	External rotation	*Pre*	0.697	Normal	0.124	Normal
		Post	0.687	Normal	0.234	Normal
		Difference	0.020	Tdk Normal	0.001	Abnormal

Within-Group Changes in Shoulder Range of Motion

The diagonal PNF intervention group showed significant improvements in shoulder ROM following the intervention period. Paired-sample t-test analysis revealed statistically significant increases in shoulder extension, abduction, adduction, internal rotation, and external rotation from pretest to posttest ($p < 0.05$). Shoulder flexion also demonstrated an increase; however, this change did not reach statistical significance ($p > 0.05$).

In contrast, the control group exhibited limited improvements in shoulder ROM. Significant pretest–posttest differences were observed only in shoulder flexion, abduction, and external rotation ($p < 0.05$), while changes in extension, adduction, and internal rotation were not statistically significant ($p > 0.05$). These results indicate that natural recovery or routine training alone produced smaller and less consistent improvements in shoulder mobility compared to the diagonal PNF intervention.

Tabel 2. Paired Difference Test and Independent Difference Test of the Effect of Diagonal Exercise on Range of Motion

Variabel		Times	PNF	Control	Difference Test
			***Mean* SD**	***Mean* SD**	
ROM	Flexion	*Pre-Test*	110.0 ± 9.88	108.42 ± 8.38	0.320
		Post-Test	124.14 ± 11.55	103.64 ± 9.48	**0.001**
		P	**0.001**	**0.012**	
		Effectiveness	11,33%	-4,61%	
	Ekstention	*Pre-Test*	37.2 ± 3.74	37.07 ± 3.60	0.320
		Post-Test	41.21 ± 3.07	38.50 ± 2.73	**0.020**

	P	**0.001**	0.057	
	Effectiveness	9,70%	3,71%	
Abduktion	*Pre-Test*	35.14 ± 2.96	35.78 ± 3.06	0.833
	Post-Test	38.71 ± 3.07	37.21 ± 3.59	0.288
	P	**0.001**	**0.017**	
	Effectiveness	9,22%	3,83%	
Adduktion	*Pre-Test*	107.57 ± 9.07	105.5 ± 8.07	0.264
	Post-Test	127.9 ± 9.12	106.8 ± 7.69	**0.001**
	P	**0.001**	0.11	
	Effectiveness	15,91%	1,27%	
Internal rotation	*Pre-Test*	70.21 ± 4.04	69.21 ± 5.07	0.284
	Post-Test	75.50 ± 4.18	70,85 ± 5.53	**0.019**
	P	**0.001**	0.101	
	Effectiveness	7,00%	2,31%	
Eksternal rotation	*Pre-Test*	73.28 ± 3.60	72.21 ± 4.28	.240
	Post-Test	79.14 ± 3.00	73.28 ± 5.06	**0.001**
	P	**0.001**	**0.031**	
	Effectiveness	-114,7%	-41,04%	

Between-Group Comparisons

Independent-sample t-test analysis of posttest ROM values revealed that the intervention group demonstrated significantly greater improvements than the control group in shoulder extension, abduction, adduction, internal rotation, and external rotation ($p < 0.05$). No significant between-group difference was observed for shoulder flexion at posttest ($p > 0.05$).

Overall, the diagonal PNF intervention group showed superior gains in shoulder ROM across most movement directions compared to the control group. These findings suggest that diagonal proprioceptive neuromuscular facilitation exercises were more effective in improving shoulder joint mobility in basketball athletes with chronic shoulder injury than routine activity without targeted intervention.

Discussion

The present study investigated the effect of diagonal proprioceptive neuromuscular facilitation (PNF) exercises on shoulder range of motion (ROM) in basketball athletes with chronic shoulder injury. The findings demonstrated that athletes who received diagonal PNF intervention experienced significantly greater improvements in most shoulder ROM parameters compared to the control group. Significant post-intervention gains were observed in shoulder extension, abduction, adduction, internal rotation, and external rotation, whereas shoulder flexion did not show a significant between-group difference. These results indicate that diagonal PNF exercises are effective in enhancing shoulder joint mobility in athletes with chronic shoulder conditions, supporting previous evidence on the role of neuromuscular facilitation in improving joint movement capacity [18].

The improvements in shoulder ROM observed in the intervention group may be explained by the underlying neuromuscular mechanisms of PNF. Diagonal PNF patterns involve multi-planar, spiral movements that stimulate proprioceptors located in muscles, tendons, and joint capsules. This proprioceptive input enhances neuromuscular coordination, reduces reflexive muscle inhibition, and facilitates more efficient motor unit recruitment during movement. As a result, the shoulder complex can move through a greater ROM with improved movement quality. Previous studies have shown that PNF-based interventions can produce superior flexibility and ROM gains compared to conventional stretching due to their integrative neuromuscular approach [19].

Notably, significant improvements were observed in shoulder rotational movements, particularly internal and external rotation. Rotational ROM is essential for basketball athletes, as overhead actions such as shooting, passing, and rebounding rely heavily on coordinated rotational shoulder mechanics. Limitations in rotational ROM have been associated with altered kinematics and increased mechanical

stress on periarticular structures in overhead athletes [20]. The diagonal PNF patterns applied in this study inherently incorporate rotational components, which may explain their effectiveness in improving rotational mobility. This finding is consistent with previous research indicating that diagonal and functional movement patterns are more effective than linear exercises for improving sport-related joint mobility.

In contrast, shoulder flexion did not demonstrate a significant between-group difference following the intervention. This result may be attributed to the high frequency of shoulder flexion movements in basketball training and daily activities, which may lead to comparable adaptive responses in both the intervention and control groups. Movements that are commonly performed tend to show smaller intervention-specific effects, as baseline mobility may already be relatively preserved. Similar findings have been reported in prior studies examining shoulder mobility interventions, where commonly used movement planes showed limited additional gains compared to less frequently trained motions [21].

Compared with existing literature, this study provides novel evidence by examining the isolated effect of diagonal PNF exercises on shoulder ROM in basketball athletes with chronic shoulder injury. Many previous studies have focused on pain reduction, neurological populations, or non-athletic clinical samples when evaluating PNF interventions. In contrast, the present study specifically targeted chronic movement limitations in an athletic population, thereby addressing a gap in sport-specific rehabilitation research. These findings extend the application of PNF beyond general rehabilitation settings and support its relevance in athletic shoulder mobility training.

From a practical standpoint, the results suggest that diagonal PNF exercises may be effectively incorporated into rehabilitation and conditioning programs for basketball athletes with chronic shoulder injury. The relatively short duration and functional nature of the intervention make it feasible for integration into regular training routines. Improved shoulder ROM may contribute to more efficient movement patterns and reduced compensatory strategies during sport-specific tasks. However, improvements in ROM alone do not directly translate to enhanced performance, and future studies should investigate the combined effects of PNF on mobility, strength, neuromuscular control, and athletic performance.

Several limitations of this study should be acknowledged. The short intervention duration and limited sample size may restrict the generalizability of the findings. Additionally, only ROM outcomes were assessed, without evaluation of muscle strength, dynamic stability, or functional performance measures. Future research should employ longer intervention periods, larger athletic samples, and multidimensional outcome measures to further clarify the role of diagonal PNF exercises in comprehensive shoulder rehabilitation for athletes.

CONCLUSION

This study demonstrates that diagonal proprioceptive neuromuscular facilitation (PNF) exercises have a significant positive effect on improving shoulder range of motion (ROM) in basketball athletes with chronic shoulder injury. Athletes who received the diagonal PNF intervention showed greater improvements in shoulder extension, abduction, adduction, internal rotation, and external rotation compared to those who did not receive targeted intervention. These findings indicate that diagonal PNF patterns are effective in enhancing shoulder joint mobility in an athletic population experiencing chronic movement limitations. The functional and multi-planar nature of diagonal PNF exercises appears to be particularly beneficial for addressing rotational and complex shoulder movements that are essential in basketball performance. By facilitating neuromuscular coordination and proprioceptive input, diagonal PNF exercises support more efficient joint motion and may help reduce movement restrictions associated with chronic shoulder injury. However, shoulder flexion did not show a significant between-group difference, suggesting that commonly used movement patterns may require different or longer intervention strategies to achieve additional gains. Overall, this study contributes novel sport-specific evidence supporting the use of diagonal PNF exercises as an effective rehabilitation approach for improving shoulder ROM in basketball athletes with chronic shoulder injury. The findings provide practical implications for sports therapists, physiotherapists, and strength and conditioning professionals in designing mobility-focused rehabilitation programs. Future research is recommended to explore longer intervention durations, larger athletic samples, and additional functional and

performance-related outcomes to further clarify the role of diagonal PNF in comprehensive shoulder rehabilitation.

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AUTHOR CONTRIBUTION STATEMENT

The writing of this article involved roles in devising the research concept and design, reviewing and analyzing relevant literature, and drafting the overall manuscript.

CONFLICT OF INTEREST AND FUNDING

There is no conflict of interest

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