



# Effect of Stretch and Hold, Ballistic, and Proprioceptive Neuromuscular Facilitation Stretching on Wrist Flexibility in Cricket Players.

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## Abstract

Wrist flexibility plays a crucial role in cricket performance, particularly in batting, bowling, and fielding. This study evaluates the effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) training, ballistic training, and stretch-and-hold training in enhancing wrist flexion among cricket players. A paired t-test was used to analyze pre-test and post-test results for both wrists, while ANCOVA and post hoc tests determined the most effective training method. The findings indicate that PNF training significantly outperformed all other methods ( $p < 0.001$ ), with post-test mean scores of 77.39 (right wrist) and 76.63 (left wrist), yielding the greatest improvement. Stretch and Hold training demonstrated moderate effectiveness, improving wrist flexion more than the Ballistic training and control group but less than PNF training. Reduced variance across all methods suggests improved performance consistency. These results highlight PNF training as the most effective approach for enhancing wrist flexibility in cricket players, followed by Stretch and Hold and Ballistic Training. These insights are valuable for athletes, coaches, and sports scientists aiming to optimize training programs for improved wrist mobility and overall performance.

**Keywords:** Wrist Flexion, Cricket Training, PNF Training, Ballistic Training, Stretch and Hold Training, Flexibility Enhancement, Sports Performance.

## 1. Introduction

Sports play a fundamental role in human life, offering a unique blend of enjoyment, competition, and physical activity. Beyond testing an individual's abilities, sports foster unity, teamwork, and social cohesion. Popular

sports such as basketball, football, cricket, volleyball, and hockey are played and watched by millions worldwide. In addition to providing recreational opportunities, sports significantly contribute to mental well-being, physical fitness, and overall personality development. Whether pursued professionally or recreationally, sports require coordination, effort, and mobility, making them an essential component of a healthy lifestyle (Siedentop & Van der Mars, 2022).

Engaging in sports regularly offers numerous benefits, particularly in enhancing physical health. Sports activities improve muscular strength, flexibility, endurance, and cardiovascular fitness. Exercise related to sports promotes healthy blood circulation, ensuring optimal oxygen and nutrient distribution throughout the body. Movements such as running, jumping, and stretching enhance speed, agility, and reflexes. Additionally, participation in sports strengthens bones and muscles, reducing the risk of injuries and chronic conditions such as diabetes, obesity, and heart disease. Sports also enhance coordination and motor skills, making everyday tasks more efficient and effortless (Zwolinsky et al., 2016).

Beyond physical health, sports play a crucial role in mental well-being. They enhance cognitive abilities by requiring quick thinking, decision-making, and problem-solving skills. Athletes must analyze their opponents, anticipate their moves, and react swiftly, sharpening their strategic thinking. These skills extend beyond sports, benefiting academic and professional pursuits. Additionally, sports help alleviate stress, anxiety, and depression by triggering the release of endorphins, the body's natural mood enhancers. A sense of achievement and increased self-esteem further support mental wellness (Hossain et al., 2024).

One of the most vital aspects of sports is teamwork. Most sports require athletes to collaborate, communicate, and work together to achieve common goals. This experience fosters essential life skills such as cooperation, leadership, and effective communication. Learning to function as a team benefits various aspects of life, including relationships, social interactions, and careers. Moreover, the discipline and commitment required in sports instill a strong work ethic, perseverance, and time management skills that prove valuable in diverse professional fields (Halldorsson et al., 2017).

Sports also unite communities and create excitement among spectators. Watching sports fosters a sense of camaraderie and strengthens social bonds. Supporters of teams form communities that enhance interpersonal connections. Local and international sporting events demonstrate the unifying power of sports, promoting cultural exchange and national pride.

For students, integrating sports into daily life is particularly important. Regular participation in sports supports a balanced lifestyle, promoting both mental and physical well-being. Studies suggest that physical activity enhances cognitive function, leading to improved academic performance, memory, and concentration. Recognizing the significance of sports, educational institutions incorporate them into curricula to foster character development and holistic growth.

Balancing physical and mental health is essential for a fulfilling life, and sports provide an effective means to achieve this balance. Whether through outdoor sports like football, hockey, cricket, and volleyball or indoor games such as chess and Sudoku, engaging in physical activity offers numerous advantages. While indoor games

enhance concentration and logical reasoning, outdoor sports build endurance and overall fitness. Sports also serve as a powerful stress reliever, helping individuals overcome challenges and maintain a positive outlook.

For professional athletes, sports offer opportunities for social recognition, financial success, and fame. Many aspiring athletes dedicate themselves to rigorous training, discipline, and perseverance to pursue careers in sports. This study specifically examines the impact of wrist flexibility on cricket players' performance and injury prevention in Kashmir. The Wrist Flexion Test is used to assess the wrist joint's range of motion, a crucial factor in batting, bowling, and fielding (Cornu et al., 2003).

Research suggests that Proprioceptive Neuromuscular Facilitation (PNF) stretching can improve range of motion and flexibility, while ballistic stretching may enhance muscle strength and power. PNF stretching has been found to increase joint mobility and reduce injury risk, whereas ballistic stretching is associated with improved performance in activities requiring explosive power. Additionally, combining Swiss ball training with PNF stretching has been shown to improve postural stability and balance in young athletes (Hidayatullah et al., 2022; Lempke et al., 2018; Feland et al., 2001).

Three stretching methods were used to increase wrist flexibility: Proprioceptive Neuromuscular Facilitation (PNF) Stretching, Ballistic Stretching, and Static Stretching (Stretch and Hold). Every approach has its own advantages, which might range from improving dynamic range of motion to gradually increasing muscle suppleness. To identify the most successful strategy, an organized training program was put into place, and post-test results were examined using statistical techniques including the ANCOVA and paired t-test. The results of this study will help Kashmiri cricket players improve their wrist flexibility, prevent injuries, and perform better, all of which will aid in their overall athletic development.

## 2. Methodology

This study aimed to evaluate the effectiveness of different stretching methods in enhancing wrist flexibility among cricketers in Kashmir. For this purpose, the researcher randomly selected 100 male cricket players from Government Higher Secondary School Pinglena and Skylight Higher Secondary School Pampore in the Kashmir region. The subjects were aged between 15 and 18 years.

The selected subjects were randomly assigned to four groups (I-IV), with each group containing 25 participants. Group I served as the control group, while Groups II-IV comprised experimental subjects undergoing different training methods: the Stretch-and-Hold training method, the Ballistic training method, and the Proprioceptive Neuromuscular Facilitation (PNF) training method, respectively. All groups (I-IV) underwent a pre-test; however, only the experimental groups (II-IV) participated in a 12-week training program, with six training sessions per week. Each morning workout lasted approximately 45 to 60 minutes, including warm-up and cool-down exercises. In this study, goniometer was used to examine the range of motion (Flexibility) of the wrist.

A pre-test and post-test design was implemented, utilizing the Wrist Flexion Test to measure flexibility and range of motion for both the right and left wrists. The primary objective was to determine which stretching technique resulted in the most significant improvement in wrist flexibility. A multi-stage statistical analysis was conducted to ensure a comprehensive evaluation of the interventions.

### Statistical Analysis

Before conducting parametric tests, the Shapiro-Wilk test was used to assess the normality of the pre-test and post-test wrist flexibility scores. A paired t-test was performed to evaluate within-group changes from pre-test to post-test for the selected dependent variables. To determine significant differences between groups, Analysis of Covariance (ANCOVA) was applied. If the F-ratio of the adjusted post-test mean was found to be significant, Scheffé's post hoc test was conducted to identify paired mean differences. The level of significance was set at 0.05.

## 3. Result and Analysis

### 3.1 Normality

For the three training techniques (Stretch and Hold, Ballistic, and PNF), the Shapiro-Wilk test was used to assess the normality of the Wrist Flexion Test (Right and Left) data. According to the test results, all p-values are higher than the standard cut-off point of 0.05, indicating that the data is normally distributed and satisfies the parametric statistical test assumption, as indicated in Table 1.

Table 1: Normality Assessment of Wrist Flexion Test Using the Shapiro-Wilk Test

	Stretch and Hold	Ballistic	PNF
Parameter	Value	Value	Value
P-value (Right)	0.4142	0.4935	0.06201
W (Right)	0.96	0.9637	0.9236
P-value (Left)	0.3223	0.8319	0.0512
W (Left)	0.9549	0.9775	0.9688

### 3.2 Wrist Flexion Test

#### Paired t-Test

*Hypothesis 1: There is no significant difference between the pre and post training among different methods (Stretch and Hold, Ballistic Training, and PNF) on the Wrist Flexion test.*

### 3.2.1 Stretch and Hold

Table 2: Paired t-Test Results for Stretch and Hold Training on Wrist Flexion Test (Right and Left) in Cricket Players.

t-Test: Paired Two Sample for Means				
	Pre-Test	Post-Test	Pre-Test	Post-Test
	Wrist Flexion Test (Right)	Wrist Flexion Test (Right)	Wrist Flexion Test (Left)	Wrist Flexion Test (Left)
Mean	74.28	76.48	73.48	75.84
Variance	9.793333	7.51	19.26	9.723333
Observations	25	25	25	25
Pearson Correlation	0.984529		0.971035	
Hypothesized Mean Difference	0		0	
Df	24		24	
t Stat	-17.0411		-7.60631	
P(T<=t) one-tail	3.27E-15		3.81E-08	
t Critical one-tail	1.710882		1.710882	
P(T<=t) two-tail	6.55E-15		7.62E-08	
t Critical two-tail	2.063899		2.063899	

The paired t-test findings for cricket players' right and left wrist flexion tests after stretch and hold training are shown in Table 2. With the variance dropping from 9.79 to 7.51, showing less unpredictability, and the mean score rising from 74.28 to 76.48 (2.96%), the right wrist demonstrated a notable improvement. In a similar vein, the variance decreased from 19.26 to 9.72 on the left wrist, which improved from 73.48 to 75.84 (3.21%). A statistically significant improvement in wrist flexibility is confirmed by the t-statistics (-17.0411 for the right and -7.60631 for the left) and incredibly low p-values. These results demonstrate how well Stretch and Hold Training works to increase cricket players' wrist mobility.

### 3.2.2 Ballistic Training

Table 3: Paired t-Test Results for Ballistic Training on Wrist Flexion Test in Cricket Players

t-Test: Paired Two Sample for Means				
	Pre-Test	Post-Test	Pre-Test	Post-Test
	Wrist Flexion Test (Right)	Wrist Flexion Test (Right)	Wrist Flexion Test (Left)	Wrist Flexion Test (Left)
Mean	74.12	75.84	73.6	75.36
Variance	7.61	4.39	9.333333	7.74
Observations	25	25	25	25
Pearson Correlation	0.955024		0.973597	
Hypothesized Mean Difference	0		0	
Df	24		24	
t Stat	-8.77734		-12.1645	
P(T<=t) one-tail	2.94E-09		4.71E-12	
t Critical one-tail	1.710882		1.710882	
P(T<=t) two-tail	5.88E-09		9.42E-12	
t Critical two-tail	2.063899		2.063899	

The paired t-test findings for cricket players' right and left wrist flexion tests after ballistic training are shown in Table 3. With the variance dropping from 7.61 to 4.39 and the mean score rising from 74.12 to 75.84 (2.32%), the right wrist demonstrated a notable improvement in consistency. Likewise, the left wrist showed a modest decrease in variance, improving from 73.6 to 75.36 (2.39%). A statistically significant improvement in wrist flexibility is confirmed by the t-statistics (-8.77734 for the right and -12.1645 for the left) and incredibly low p-values. These results show that cricket players' wrist mobility can be efficiently increased by ballistic training.

### 3.2.3 Proprioceptive Neuromuscular Facilitation

Table 4: Paired t-Test Results for PNF Training on Wrist Flexion Test in Cricket Players

t-Test: Paired Two Sample for Means				
	Pre-Test	Post-Test	Pre-Test	Post-Test
	Wrist Flexion Test (Right)	Wrist Flexion Test (Right)	Wrist Flexion Test (Left)	Wrist Flexion Test (Left)
Mean	74.4	77.56	73.76	76.8
Variance	15.41667	11.34	13.02333	8.833333
Observations	25	25	25	25
Pearson Correlation	0.987611		0.958761	
Hypothesized Mean Difference	0		0	
Df	24		24	
t Stat	-19.75		-13.3829	
P(T<=t) one-tail	1.19E-16		6.33E-13	
t Critical one-tail	1.710882		1.710882	
P(T<=t) two-tail	2.38E-16		1.27E-12	
t Critical two-tail	2.063899		2.063899	

The paired t-test findings for cricket players' right and left wrist flexion tests after PNF training are shown in Table 4. With the variance falling from 15.42 to 11.34 and the mean score rising from 74.4 to 77.56 (4.25%), the right wrist demonstrated a notable improvement, suggesting increased consistency. In a similar vein, the left wrist showed less fluctuation, improving from 73.76 to 76.8 (4.12%). A statistically significant improvement in wrist flexibility is confirmed by the t-statistics (-19.75 for the right and -13.3829 for the left) and incredibly low p-values. These results demonstrate that PNF Training is a very successful strategy for enhancing cricket players' wrist mobility.

### 3.4 Comparison of Training Methods for Wrist Flexion in Cricketers

PNF Training is the most successful technique for improving wrist flexion in cricket players, according to a comparison of Stretch and Hold Training, Ballistic Training, and PNF Training. With the most significant statistical result ( $t = -19.75$ ,  $p < 0.001$ ), PNF Training improved the right wrist the most (4.25%), raising the mean score from 74.4 to 77.56. Ballistic training showed the smallest gain (2.32%), while Stretch and Hold training showed a modest improvement (2.96%), both of which were nevertheless statistically significant ( $p < 0.001$ ).

A similar pattern was shown for the left wrist, where PNF training produced the greatest improvement (4.12%), followed by Stretch and Hold Training (3.21%) and Ballistic Training (2.39%), and, all of which were statistically significant ( $p < 0.05$ ). Greater consistency in post-test performance was indicated by a decrease in variance across all approaches. These results are shown in Figure 1, which highlights PNF Training as the best method for improving cricket players' wrist flexibility. Stretch and Hold Training also offers significant advantages. Despite its effectiveness, ballistic training produced the least improvement.

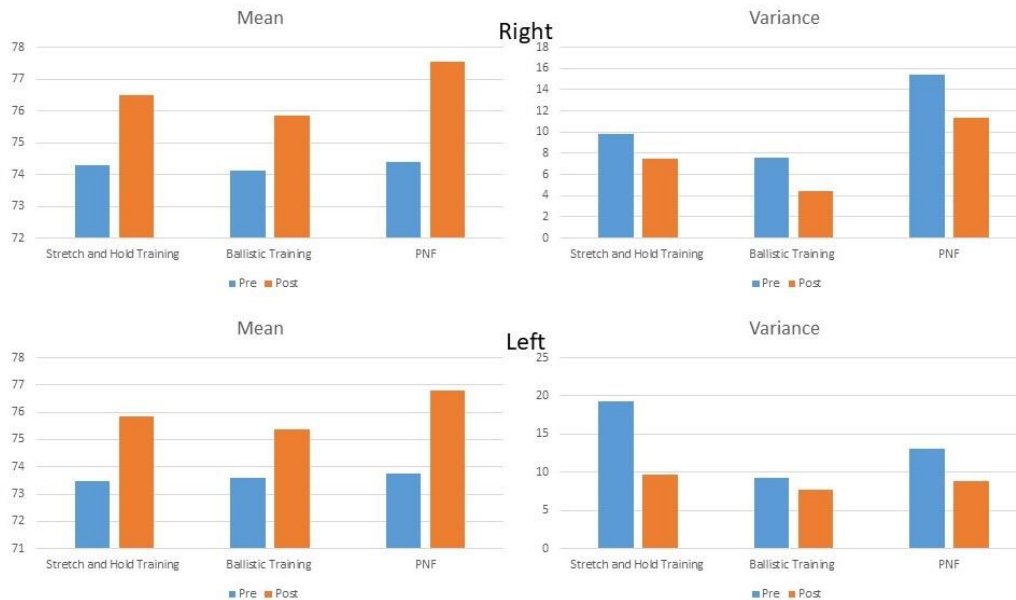


Figure 1: Comparison of Training Methods for Wrist Flexion in Cricketers



Figure 2: Percentage Improvement across Different Training Methods

The proportionate improvement in wrist flexion performance among cricket players following various training techniques is graphically depicted in Figure 2. Ballistic training provides the least increase (24–25%), whereas PNF training shows the most improvement (42–45%), followed by Stretch and Hold training (31–33%). These outcomes support PNF Training as the best technique for increasing wrist flexibility and are consistent with the

statistical data. These variations might be clearly seen in a pie chart or bar chart, which would also illustrate the better benefit of PNF training on cricket players' wrist mobility.

### 3.5 ANOCVA Wrist Flexion Test (Right and Left)

*Hypothesis 2: There is no significant difference in post-test hamstring and lower back flexibility scores among the four training groups (Control, Stretch and Hold, Ballistic Training, and PNF Training) after adjusting for pre-test scores.*

#### 3.5.1 ANOCVA Wrist Flexion Test (Right)

Table 5: ANCOVA result on the Wrist Flexion Test (Right).

Source	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Pre-Test (Covariate)	1	741.1	741.1	2429	< 2e-16
Group (Training Method)	3	128.9	43	140.9	< 2e-16
Residuals	95	29	0.3		

The use of ANCOVA to adjust for early differences and enhance accuracy in group comparisons is justified by the very significant Pre-Test (Covariate) ( $p < 2e-16$ ), which shows that pre-test scores have a considerable impact on post-test wrist flexion findings. Additionally, the Group Effect is extremely significant ( $p < 2e-16$ ), indicating that the improvement in wrist flexion is statistically significantly impacted by the various training approaches. The model's dependability is further supported by the residual sum of squares (29.0) and mean square (0.3), which indicates little unexplained variance. Furthermore, as seen in Table 5, the extremely high F-value (140.9) emphasizes the training approaches' potent impact on wrist flexibility and their efficacy in improving wrist mobility.

#### 3.5.2 Post-Hoc Analysis

Since the Group effect is significant, a pairwise comparison determines which training methods differ significantly.

Table 6: Estimated Marginal Means (Post-Test Scores per Group)

Group	Estimated Mean (emmean)	SE	95% CI (Lower - Upper)
Ballistic Training	75.91	0.11	(75.69 - 76.13)
Control Group	74.25	0.111	(74.03 - 74.47)

PNF Training	77.39	0.111	(77.17 - 77.61)
Stretch and Hold	76.41	0.11	(76.19 - 76.63)

The Wrist Flexion Test's Estimated Marginal Means (Post-Test Scores per Group) are shown in the table 6, which contrasts various training approaches. According to the data, the Control Group scored the lowest (74.25), while PNF Training produced the highest estimated mean score (77.39), followed by Stretch and Hold (76.41) and Ballistic Training (75.91). All groups have a Standard Error (SE) of roughly 0.11, which guarantees uniformity in measurement accuracy. With PNF Training showing the most notable increase in wrist flexibility (77.17 - 77.61), the 95% Confidence Intervals (CI) show the range that the true population mean is anticipated to lie within. These results imply that PNF Training is the most successful strategy for increasing flexibility, although all three stretching strategies successfully increase wrist flexion when compared to the control group.

### 3.5.3 Pairwise Comparisons between Groups

Table 7: Pairwise Comparisons between Groups

Contrast	Mean Difference	SE	t-value	p-value
Ballistic - Control	1.658	0.156	10.61	< 0.0001
Ballistic - PNF	-1.481	0.156	-9.477	< 0.0001
Ballistic - Stretch	-0.504	0.156	-3.223	0.0104
Control - PNF	-3.139	0.156	-20.072	< 0.0001
Control - Stretch	-2.161	0.156	-13.827	< 0.0001
PNF - Stretch	0.978	0.156	6.258	< 0.0001

#### *Result of Table 7*

1. PNF Training achieved the highest post-test wrist flexion scores (Mean = 77.39), which were significantly higher than those of all other groups.
2. Stretch and Hold Training was moderately effective, outperforming the Control group but falling slightly short of PNF Training.
3. Ballistic Training led to a significant improvement in wrist flexion compared to the Control group, but it was less effective than PNF Training.

4. The Control group had the lowest post-test scores, with significantly less improvement compared to all other training methods.

### 3.6 Wrist Flexion Test (Left)

#### 3.6.1 ANCOVA Wrist Flexion Test (Left)

Table 8: ANCOVA result on the Wrist Flexion Test (Left).

Source	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Pre-Test (Covariate)	1	748.4	748.4	1305.19	< 2e-16
Group (Training Method)	3	122.4	40.8	71.17	< 2e-16
Residuals	95	54.5	0.6		

The pre-test scores (covariate) are highly significant ( $p < 2e-16$ ), indicating that they strongly influence the post-test wrist flexion results. This justifies the use of ANCOVA to adjust for initial differences and enhance the accuracy of group comparisons. The group effect is also highly significant ( $p < 2e-16$ ), confirming that different training methods have a statistically significant impact on wrist flexion improvements. Additionally, the relatively low residual sum of squares (54.5) and mean square (0.6) suggest that most of the variability in the results is explained by the model. This further reinforces the effectiveness of the training interventions in improving wrist flexibility, as shown in Table 8.

#### 3.6.2 Post-Hoc Analysis

Since the Group effect is significant, a pairwise comparison determines which training methods differ significantly.

Table 9: Estimated Marginal Means (Post-Test Scores per Group)

Group	Estimated Mean (emmean)	SE	95% CI (Lower - Upper)
Ballistic Training	75.32	0.151	(75.02 - 75.62)
Control Group	73.63	0.152	(73.33 - 73.93)
PNF Training	76.63	0.152	(76.33 - 76.93)
Stretch and Hold	75.9	0.151	(75.59 - 76.20)

Table 9 displays the Estimated Marginal Means (Post-Test Scores per Group) for wrist flexion improvement across different training methods. The PNF Training group achieved the highest estimated mean score (76.63),

followed by Stretch and Hold (75.90) and Ballistic Training (75.32), while the Control Group had the lowest score (73.63). The Standard Error (SE) is approximately 0.151-0.152 for all groups, ensuring measurement precision. The 95% Confidence Intervals (CI) indicate that the true population means likely fall within the provided ranges, with PNF Training (76.33 - 76.93) showing the most significant improvement in wrist flexibility. These results suggest that all three training methods effectively enhance wrist flexion compared to the control group, with PNF Training being the most effective approach.

### 3.6.3 Pairwise Comparisons between Groups

Table 10: Pairwise Comparisons between Groups

Contrast	Mean Difference	SE	t-value	p-value
Ballistic - Control	1.69	0.214	7.89	< 0.0001
Ballistic - PNF	-1.314	0.214	-6.133	< 0.0001
Ballistic - Stretch	-0.575	0.214	-2.683	0.0516
Control - PNF	-3.004	0.214	-14.014	< 0.0001
Control - Stretch	-2.265	0.214	-10.576	< 0.0001
PNF - Stretch	0.739	0.214	3.448	0.0051

#### Result of Table 10:

1. PNF Training achieved the highest wrist flexion scores (Mean = 76.63), which were significantly higher than those of all other groups.
2. Ballistic Training resulted in significantly better wrist flexion scores compared to the Control group but was significantly lower than PNF Training.
3. The Control group had the lowest post-test scores, demonstrating significantly lower improvements compared to all other training methods.
4. Stretch and Hold Training was better than the Control group but did not significantly differ from Ballistic Training ( $p = 0.0516$ ).

#### Conclusion

This research investigated the impact of PNF Training, Ballistic Training, and Stretch and Hold Training on wrist flexion in cricket players. The results consistently demonstrate that PNF Training is the most effective, achieving the highest post-test scores for both the right (Mean = 77.39) and left (Mean = 76.63) wrists (Table 7 & Table

10). While Ballistic Training significantly enhanced wrist flexibility compared to the Control group, it was less effective than PNF Training. Stretch and Hold Training showed moderate effectiveness, surpassing the Control group but with slightly lower improvements than PNF. The Control group had the least improvement, underscoring the importance of targeted training interventions for increasing wrist flexibility. PNF Training is the preferred method for maximizing wrist flexion in cricket players, followed by Hold Training and Ballistic and Stretch Training. These findings highlight the significance of choosing effective flexibility training techniques to enhance performance. Future research might examine long-term adaptations and sport-specific benefits of these methods for cricket and other athletic disciplines.

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