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EFFECTIVENESS OF DYNAMIC STRETCHING VERSUS HOLD-RELAX PNF STRETCHING TO IMPROVE HAMSTRING FLEXIBILITY IN WRESTLERS

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ABSTRACT

Background: Hamstring flexibility plays a vital role in the performance, agility, and injury prevention of wrestlers. Limited hamstring flexibility is a common problem that can lead to decreased athletic performance and increased risk of muscle strain. Stretching techniques such as Dynamic Stretching (DS) and Hold-Relax Proprioceptive Neuromuscular Facilitation (PNF-HR) are widely used to improve flexibility, yet their comparative effectiveness among wrestlers remains uncertain.

Aim: To compare the effectiveness of Dynamic Stretching and Hold-Relax PNF Stretching in improving hamstring flexibility among wrestlers.

Methodology: A comparative study was conducted on 36 wrestlers with hamstring tightness, divided equally into two groups. Group A performed Dynamic Stretching and Group B performed Hold-Relax PNF Stretching for 1 week on alternate days. Outcome measures included the 90-90 Straight Leg Raise Test and Knee Range of Motion (ROM) measured pre- and post-intervention using a goniometer. Statistical analysis was performed using paired and unpaired t-tests.

Results: Both Dynamic Stretching and Hold-Relax PNF Stretching significantly improved hamstring flexibility within each group ($p < 0.05$). However, Hold-Relax PNF Stretching showed a slightly greater mean improvement in 90-90 SLR angle and knee extension ROM compared to Dynamic Stretching, though the difference between groups was not statistically significant.

Conclusion: Both stretching techniques are effective in improving hamstring flexibility in wrestlers, but Hold-Relax PNF stretching may offer a marginally better outcome. This finding supports the inclusion of both stretching methods in wrestling warm-up and rehabilitation routines to enhance flexibility and reduce the risk of injury.

Keywords: Dynamic stretching, Hamstring flexibility, Hold Relax PNF, Range of Motion, Wrestlers, 90-90 SLR.

INTRODUCTION

Wrestling is a high-intensity, contact sport that requires strength, endurance, flexibility, and agility to push, pull, and fight against an opponent. It is widely believed that stretching increases flexibility and improves the performance among athletes[1]. Hamstring muscle strain is one of the most common injuries in sports. Muscular flexibility is an important aspect of human normal function. Limited flexibility has been shown to predispose a person to several musculoskeletal injuries and significantly affect a person's level of function.

A pre-exercise routine is practised by most individuals who participate in sports. So, the optimal physical routine is initiated. Stretching is the most common technique for enhancing hamstring flexibility and preventing injuries.

Dynamic stretching involves moving the limb from its neutral position to its end range, where the muscles are at greatest length, and then moving it back to its original position. Dynamic action should be given in a smooth, controlled manner. It also involves movements that take the muscle through its full range of motion, enhancing blood flow and muscle temperature.[2]

Hamstring stretching is also done using the PNF stretching technique, which includes the Hold-relax technique, which involves lengthening the muscle to the point of limitation, at which point the individual performs an isometric contraction for up to 10 seconds, followed by passive movement of the limb into the new end range. Hold-relax PNF promote muscle relaxation and increased length through autogenic inhibition.[3] The ability of an athlete to move smoothly depends on flexibility. The hamstrings are the muscle group that tends to get shortened. Three muscles, collectively known as the hamstrings, cover the posterior thigh: the semitendinosus, the semimembranosus, and the biceps femoris.

Muscle tightness is caused by reduced muscle ability to deform, resulting in reduced range of motion at the joint it acts on. Inability to achieve greater than 160 degrees of knee extension with the hip at 90 degrees of flexion is considered hamstring tightness. Hamstring tightness is measured by the 90-90 SLR test. Hamstring tightness can lead to hamstring injuries, which are most common in wrestlers.[4]

Knee range of motion (ROM) is also a reliable, objective measure used to assess hamstring flexibility. Since the hamstring muscle crosses both the hip and the knee joints, any tightness restricts knee extension when the hip is flexed. Measuring active or passive knee extension, such as Active Knee Extension (AKE) or Passive Straight Leg Raise (SLR), provides a quantitative evaluation of hamstring flexibility.[5]

The most effective stretching method for improving hamstring flexibility in wrestlers is unclear, making it essential to compare different techniques. There is limited research that specifically compares dynamic stretching and Hold-relax PNF stretching for hamstring flexibility in wrestlers. The study aimed to compare the effectiveness of Dynamic Stretching and Hold-Relax PNF Stretching for improving hamstring flexibility among wrestlers.

Methodology

An experimental study was conducted in the physiotherapy department of the Maharashtra Institute of Physiotherapy, Latur, following approval from the institutional ethics committee. After obtaining informed consent, 36 wrestlers with Hamstring tightness were assigned to groups A and B (18 participants in each group) using simple random sampling by an independent collaborator via opaque, sealed envelopes. Both male and female wrestlers were included if they met the following criteria: Age group 18 years -30 years, having bilateral hamstring tightness and were involved in practice at least 4 times a week. Participants having recent trauma or any sports injury, hip and knee joint surgery, athletes who were not regularly involved in training and competing in wrestling and having other pathological conditions involving the lower back and hamstring muscle were excluded. Baseline data on hamstring tightness were obtained using the 90-90 test, and knee range of motion was measured using a universal goniometer. The outcomes were assessed at baseline and at 1 week.

Participants in group A received dynamic hamstring stretching. All the pre-treatment outcomes were measured according to the protocol. For dynamic stretching, each participant was instructed to actively swing the leg to be stretched forward into hip flexion until a stretch was felt in the posterior thigh, keeping the knee extended and the ankle plantarflexed while standing. Then the leg was allowed to swing back into slight hip extension. Dynamic stretching was performed for 30 sec, in 10 sets, with a 20 sec rest period between sets for 1 week, every alternate day, consisting of repeated hip flexion/extension swinging movements.

Participants in group B received the hold-relax PNF stretching technique. All the pre-treatment outcomes were measured according to protocol. For the Hold-relax, the participant was positioned supine. The therapist lifted the participant's leg straight up for a gentle hamstring stretch and asked the participant to apply force on the therapist's hand towards extension. The therapists provide resistance for 5 to 10 sec, then ask the participant to relax. After that, the therapist gently moves the leg to reach a new barrier, and the stretch was maintained for 5 to 10 seconds. 3 sets of 10 repetitions, 3 times a week, every alternate day.

The data was collected and analysed using Microsoft Excel. Intragroup comparisons of the study parameter in each group before and after the intervention were performed using a paired t-test. Intergroup comparison of study parameters between the two groups was performed using an unpaired t-test.

Results

Table 1: Description of Mean Flexibility of Hamstring before and after Dynamic stretching among Wrestlers. (Group A).

Parameters	Dynamic Stretching Exercise			
	Pre –test		Post-Test	
	Mean	S. D	Mean	S. D
SLR Right	153.50	±04.66	156.11	± 05.24
SLR Left	153.33	±04.49	156.33	05.29
Knee Flexion Right	121.44	±01.78	122.6	±02.03
Knee Flexion Left	121.50	±02.12	123	±02.52
Knee Extension Right	10	±01.084	08.88	±01.078
Knee Extension Left	10	±01.188	08.98	±01.231

The data presented in Table 1 and figure 1 below reveals the SLR of Right and Left Lower limbs Pre-test and Post-test scores of Flexibility, In case of SLR Right lower limb at pre-test the Mean flexibility of Hamstring was 155.5 with Standard deviation + 04.66 while at Post – test the Mean flexibility was 156.11 with standard deviation + 05.24, in case of SLR Left Lower limb, during Pre-test the Mean flexibility of Hamstring was 153.33 with Standard deviation +04.49 at Post-Test the Mean Flexibility was 156.33 with Standard deviation +05.29.

For Knee flexion ROM as per the data presented in Table 1 and Figure 2 (below) reveals thatKnee Flexion of Right and Left Lower limbs Pre-test and Post-test scores of Flexibility, In case of Knee Flexion of Right lower limb at pre-test the Mean flexibility of Hamstring was 121.44 with Standard deviation + 01.78 while at Post –test the Mean flexibility was 122.60 with standard deviation + 02.03, in case of Knee Flexion of Left Lower limb, during Pre-test the Mean flexibility of Hamstring was 121.50 with Standard deviation +02.12 at Post-Test the Mean Flexibility was 123 with Standard deviation +02.52.

The data presented in Table 1 and Figure 3 below reveals the Knee Extension of Right and Left Lower limbs Pre-test and Post-test scores of Flexibility, In case of Knee Extension of Right lower limb at pre-test the Mean flexibility of Hamstring was 10 with Standard deviation + 01.88 while at Post –test the Mean flexibility was 08.98 with standard deviation + 01.231, in case of Knee extension of Left Lower limb, during Pre-test the Mean flexibility of Hamstring was 10 with Standard deviation +01.084 at Post-Test the Mean Flexibility was 08.88 with Standard deviation +01.078.

Figure 1: SLR of Right and Left Lower limbs, Pre-test and Post-test scores of Flexibility (Group A)

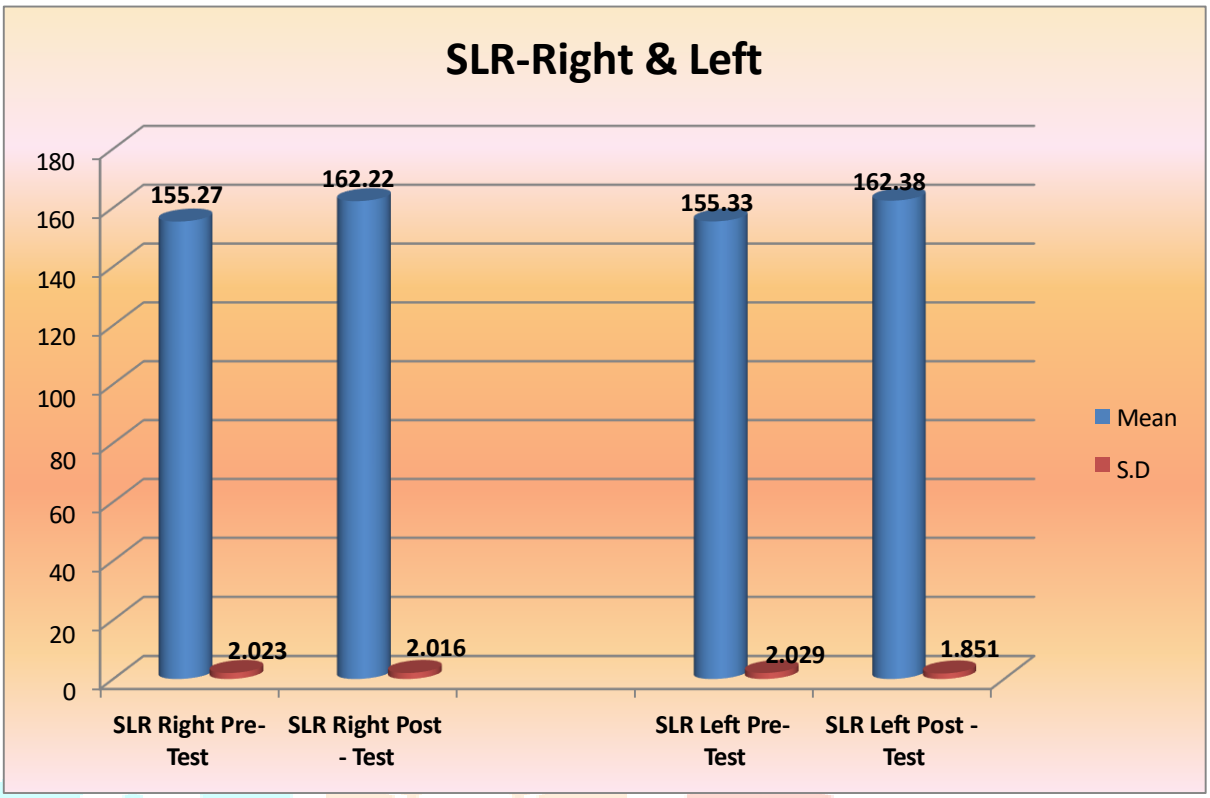

Figure 2: Knee Flexion of Right and Left Lower Limbs: Pre-test and Post-test scores of Flexibility (Group A).

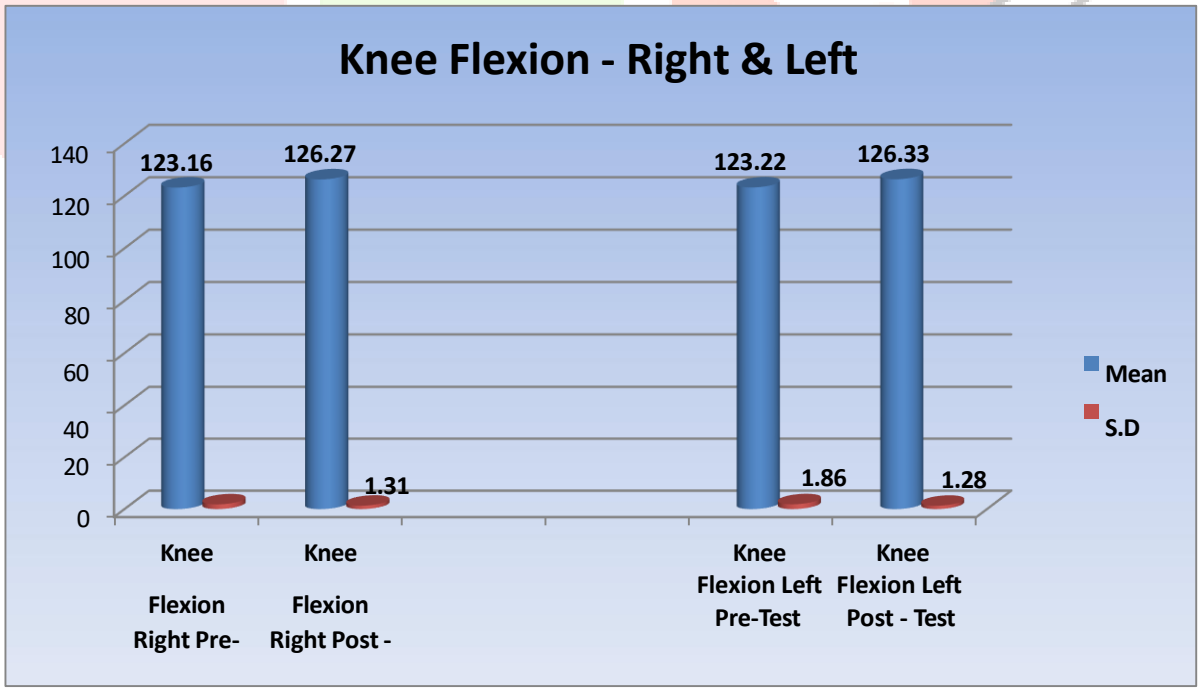

Figure 3: Knee Extension of Right and Left Lower Limbs: Pre-test and Post-test Scores of Flexibility. (Group A)

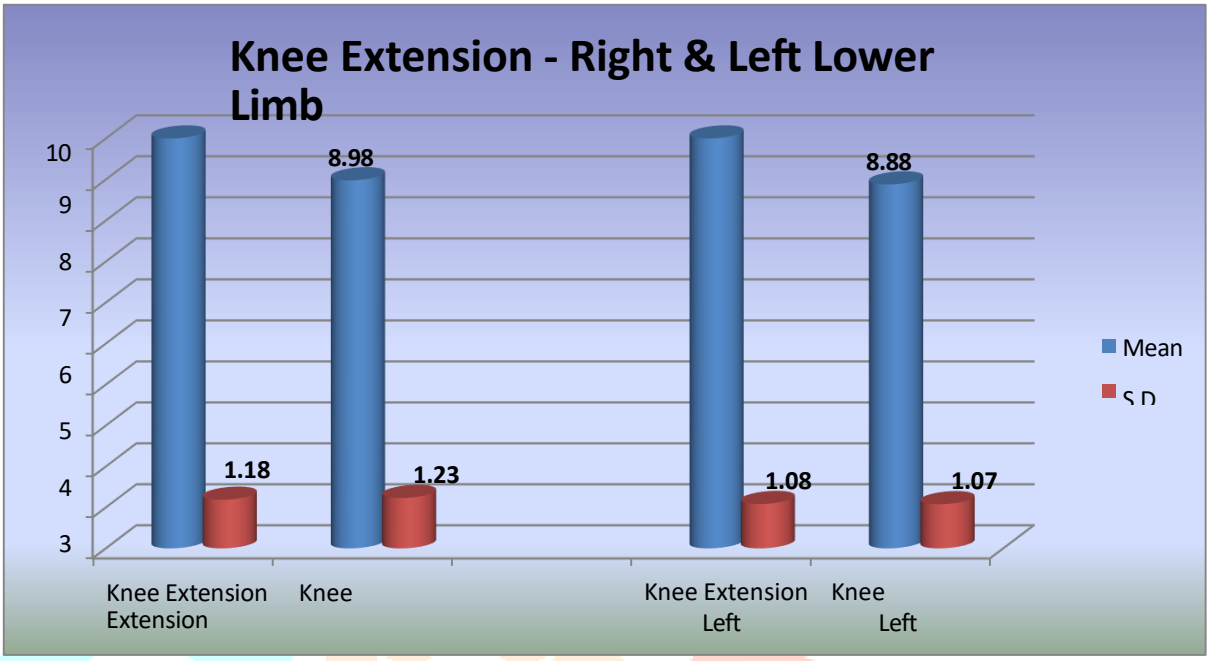

Table 2: Description of Mean Flexibility of Hamstring before and after Hold-Relax PNF Exercise among Wrestlers (Group B).

Parameters	Hold-Relax PNF Exercise			
	Pre –test		Post-Test	
	Mean	S. D	Mean	S. D
SLR Right	155.27	±02.023	162.22	± 02.01
SLR Left	153.33	±02.029	162.38	±01.851
Knee Flexion Right	123.16	±01.851	126.27	±01.319
Knee Flexion Left	123.22	±01.864	126.33	±01.238
Knee Extension Right	9.50	±01.043	07.66	±01.188
Knee Extension Left	9.50	±01.043	07.66	±01.188

The data (group B) presented in Table 2 and Figure.no 4 below reveals the SLR of Right and Left Lower limbs Pre-test and Post-test scores of Flexibility, In case of SLR Right lower limb at pre-test the Mean flexibility of Hamstring was 155.27 with Standard deviation + 02.023 while at Post –test the Mean flexibility

was 162.22 with standard deviation + 02.016, in case of SLR Left Lower limb, during Pre-test the Mean flexibility of Hamstring was 155.33 with Standard deviation +02.029 at Post-Test the Mean Flexibility was 162.38 with Standard deviation +01.851.

The data presented in Table 2 and Figure 5 reveals the Knee Flexion of Right and Left Lower limbs Pre-test and Post-test scores of Flexibility, In case of Knee Flexion of Right lower limb at pre-test the Mean flexibility of Hamstring was 123.16 with Standard deviation + 01.82 while at Post –test the Mean flexibility was 126.27 with standard deviation + 01.31, in case of Knee Flexion of Left Lower limb, during Pre-test the Mean flexibility of Hamstring was 123.22 with Standard deviation +01.86 at Post-Test the Mean Flexibility was 126.33 with Standard deviation +01.28.

The data presented in Table 2 and Figure 6 reveals the Knee Extension of Right and Left Lower limbs Pre-test and Post-test scores of Flexibility, In case of Knee Extension of Right lower limb at pre-test the Mean flexibility of Hamstring was 9.5 with Standard deviation + 01.043 while at Post –test the Mean flexibility was 07.66 with standard deviation + 01.188, in case of Knee extension of Left Lower limb, during Pre-test the Mean flexibility of Hamstring was 09.5 with Standard deviation +01.188 at Post-Test the Mean Flexibility was 07.86 with Standard deviation +01.188.

Figure 4: SLR of Right and Left Lower limbs Pre-test and Post-test scores of Flexibility (group B).

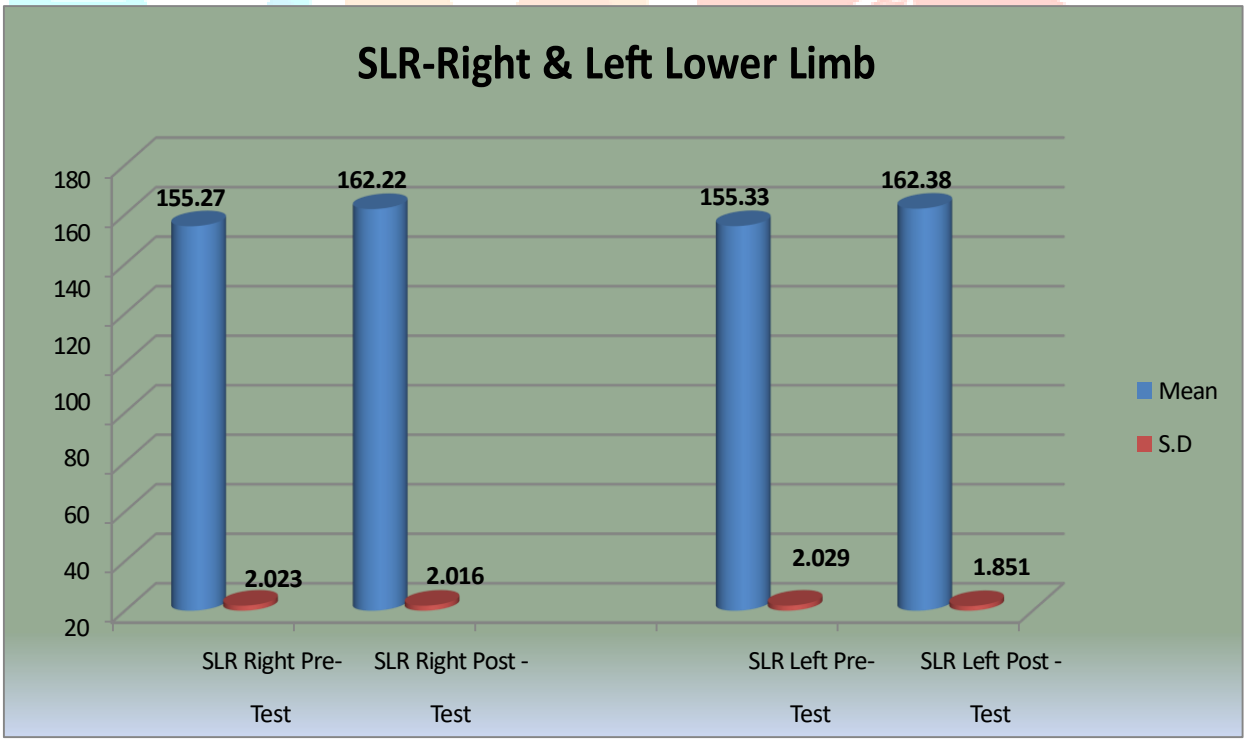

Figure 5: Knee Flexion of Right and Left Lower Limbs: Pre-test and Post-test scores of Flexibility (Group B).

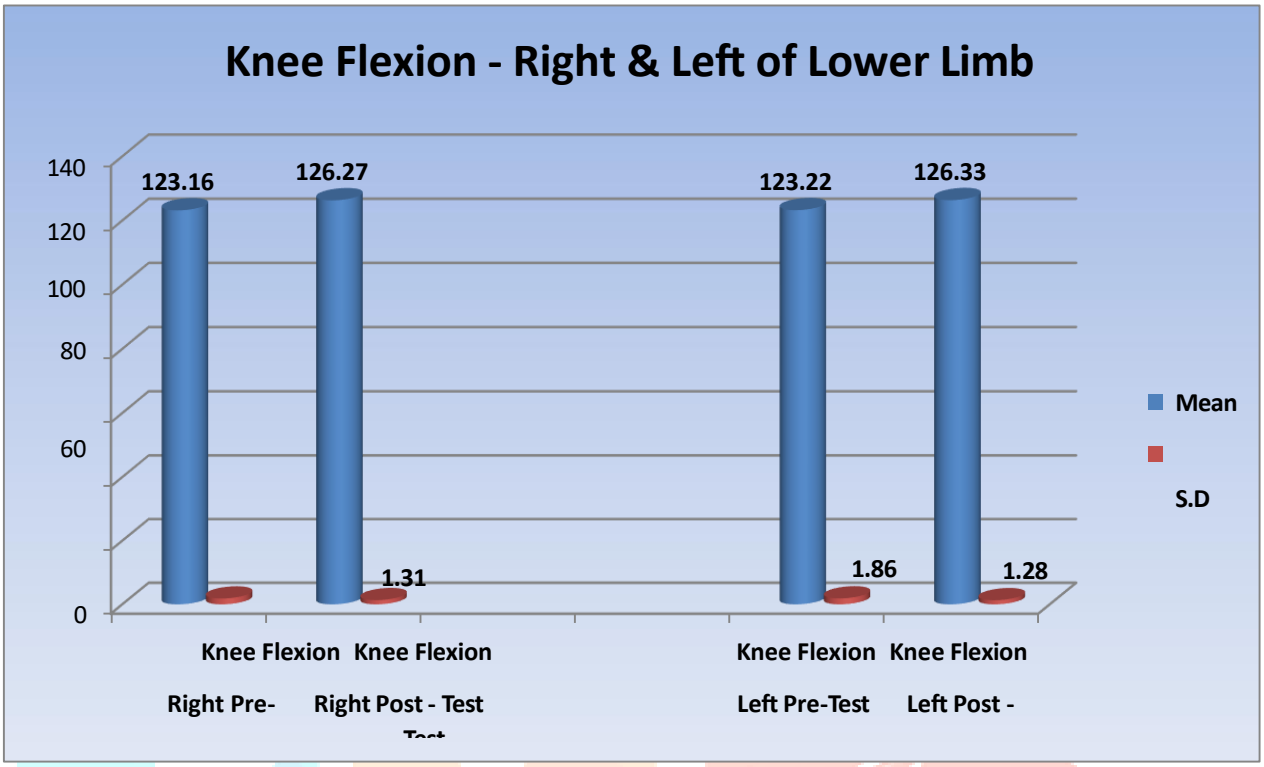

Figure 6: Knee Extension of Right and Left Lower Limbs: Pre-test and Post-test scores of Flexibility (Group B).

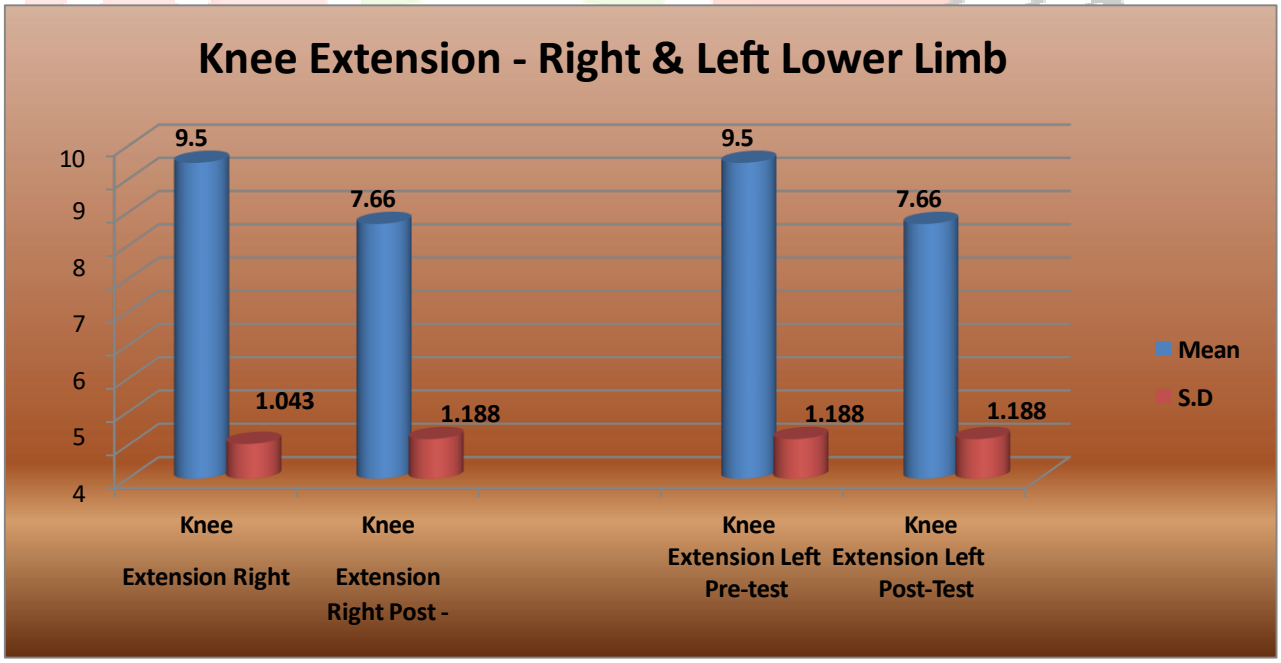

Table No 3: Pre-test post-test comparison in group A.

Dynamic Stretching	Mean	St. Deviation	St. Error Mean	t	do	P-Value
Flexibility of SLR Right Lower limb	02.611	±01.243	0.293	08.910	17	0.00
Flexibility of SLR Left Lower Limb	02.666	±01.455	.343	07.775	17	0.00
Flexibility of Knee Flexion Right Lower Limb	1.388	±01.334	.314	04.415	17	0.00
Flexibility of Knee Flexion Left Lower Limb	1.500	±01.248	.2942	05.097	17	0.00

't' 2.056, (17) = P<0.05

The data presented in table 3 shows the Mean Hamstring Flexibility of Wrestlers before and after Dynamic Stretching exercise, in case of SLR of Right lower limb the Mean flexibility score was 02.611 with standard deviation ±01.243 and standard error of 0.293, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 08.910 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Dynamic Stretching exercise was successful in enhancing flexibility among the samples, while in case of SLR of Left lower limb the Mean flexibility score was 02.666 with standard deviation ±01.455 and standard error of 0.343, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't'

was 07.775 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Dynamic Stretching exercise was successful in enhancing flexibility among wrestlers.

In case of Knee Flexion of Right lower limb the Mean flexibility score was 01.388 with standard deviation ±01.334 and standard error of 0.314, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 04.415 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Dynamic Stretching exercise was successful in enhancing flexibility.

In case of Knee Flexion of Left lower limb the Mean flexibility score was 01.500 with standard deviation ±01.249 and standard error of 0.294, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 05.097 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Dynamic Stretching exercise was successful in enhancing flexibility among the wrestlers.

In case of Knee Extension of Right lower limb the Mean flexibility score was 01.11 with standard deviation ±0.8323 and standard error of 0.196, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 05.664 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Dynamic Stretching exercise was successful in enhancing flexibility among wrestlers.

In case of Knee Extension of Left lower limb the Mean flexibility score was 1.12 with standard deviation ±0.983 and standard error of .796, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 04.66 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Dynamic Stretching exercise was successful in enhancing flexibility among the wrestlers.

Table 4: Table No 3: Pre-test post-test comparison in group B.

Hold-Relax PNF Exercise	Mean	St. Deviation	St. Error Mean	t	def.	P-Value
Flexibility of SLR Right Lower limb	06.944	±01.211	0.285	24.323	17	0.00
Flexibility of SLR Left Lower Limb	07.055	±0.9983	.235	29.983	17	0.00
Flexibility of Knee Flexion Right Lower Limb	3.111	+01.231	.290	10.719	17	0.00

Flexibility of Knee Flexion Left Lower Limb	3.122	+01.241	.294	10.971	17	0.00
Flexibility of Knee Extension Right Lower Limb	1.833	+0.707	.16671	11.00	17	0.00
Flexibility of Knee Extension Left Lower Limb	1.834	0.780	.1687	11.01	17	0.00

't' (17) = 2.056, P<0.05

The data presented in table.no-04 shows the Mean Hamstring Flexibility of Wrestlers before and after Hold-Relax PNF exercise, in case of SLR of Right lower limb the Mean flexibility score was 06.944 with standard deviation ±01.211 and standard error of 0.285, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 24.323 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Hold-Relax PNF exercise was successful in enhancing flexibility among the samples, while in case of SLR of Left lower limb the Mean flexibility score was 07.055 with standard deviation +0.9983 and standard error of 0.235, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 29.983 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Hold-Relax PNF exercise was successful in enhancing flexibility among the samples.

In case of Knee Flexion of Right lower limb the Mean flexibility score was 3.111 with standard deviation +01.231 and standard error of .290, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 10.791 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Hold-Relax PNF exercise was successful in enhancing flexibility among the samples, while

In case of Knee Flexion of Left lower limb the Mean flexibility score was 3.122 with standard deviation +01.241 and standard error of .294, paired t-test was computed in order to find significant difference in mean scores before and after intervention, the calculated 't' was 10.971 which was higher than the table value (t(17) =2.056) and the P-value was lower than 0.05 indicating Hold-Relax PNF exercise was successful in enhancing flexibility among the samples.

In case of Knee Extension of Right lower limb, the Mean flexibility score was 1.833 with standard deviation +0.707 and standard error of .16671, paired t-test was computed in order to find a significant difference in mean scores before and after intervention; the calculated 't' was

11.00, which was higher than the table value (t(17) =2.056), and the P-value was lower than 0.05, indicating the Hold-Relax PNF exercise was successful in enhancing flexibility among wrestlers.

In case of Knee Extension of Left lower limb, the Mean flexibility score was 1.834 with standard deviation ±0.780 and standard error of .1687, paired t-test was computed in order to find a significant difference in mean scores before and after intervention; the calculated 't' was
11.01, which was higher than the table value (t(17) =2.056), and the P-value was lower than 0.05, indicating the Hold-Relax PNF exercise was successful in enhancing flexibility among the samples.

Table 5: Comparison between Group A and Group B SLR Right Leg

SLR of Right Lower Limb	Mean	Mean difference	Standard Error Difference	Independent't' test	P-Value
Dynamic Stretching Exercise	156.11	6.111	1.238	04.614	0.02
Hold-Relax PNF Exercise	162.22				

The data presented in table 5 shows the Mean difference between Dynamic stretching exercise and Hold-Relax PNF is 6.111, To find significant Mean difference for enhanced flexibility, Independent `t`-test was computed and obtained `t`(36) = 04.614 is found to be significant at 0.05 level of significance, as computed `t` value is higher than table Value (2.04) indicating Null Hypothesis is rejected implying there is significant difference between two interventions. As the Mean of Hold-Relax PNF Exercise has a higher mean than Dynamic stretching exercise, hence Hold-Relax PNF Exercise has a more pronounced effect than Dynamic stretching exercise in enhancing Flexibility among Wrestlers.

Table 6: Comparison between Group A and Group B SLR Left Leg.

SLR of Left Lower Limb	Mean	Mean difference	Standard Error Difference	Independent't test	P-Value
Dynamic Stretching Exercise	156.33	6.055	1.321	04.583	0.02
Hold-Relax PNF Exercise	162.38				

The data presented in table.no 6 shows the Mean difference between Dynamic stretching exercise and Hold-Relax PNF is 6.055, To find significant Mean difference for enhanced flexibility, Independent `t`-test was computed and obtained `t`(34) = 04.583 is found to be significant at 0.05 level of significance, as computed `t` value is higher than table Value (2.04) indicating Null Hypothesis is rejected implying there is significant difference between two interventions. As the Mean of Hold-Relax PNF Exercise has higher mean than Dynamic stretching exercise, hence Hold-Relax PNF Exercise has pronounced effect than Dynamic stretching exercise in enhancing Flexibility among Wrestlers.

Table 7: Difference between hamstring flexibility of Group A and Group B Right Leg of knee flexion ROM

Knee Flexion of Right Lower Limb	Mean	Mean difference	Standard Error Difference	Independent 't' test	P-Value
Dynamic Stretching Exercise	122.83	3.44	0.628	05.498	0.00
Hold-Relax PNF Exercise	126.27				

The data presented in table.no – 7 shows the Mean difference between Dynamic stretching exercise and Hold-Relax PNF is 3.44, To find significant Mean difference for enhanced flexibility, Independent `t`-test was computed and obtained `t`(36) = 05.498 is found to be significant at 0.05 level of significance, as computed `t` value is higher than table Value (2.04) indicating Null Hypothesis is rejected implying there is significant difference between two interventions. As the Mean of the Hold-Relax PNF Exercise is higher than that of the Dynamic stretching exercise, the Hold-Relax PNF Exercise has a more pronounced effect than the Dynamic stretching exercise in enhancing Flexibility among Wrestlers.

Table 8: Difference between hamstring flexibility of Group A and Group B, Left Leg of knee flexion ROM.

Knee Flexion of Left Lower Limb	Mean	Mean difference	Standard Error Difference	Independent 't' test	P-Value
Dynamic Stretching Exercise	123.00	3.33	0.666	05.000	0.00
Hold-Relax PNF Exercise	126.33				

The data presented in table 8 shows the Mean difference between Dynamic stretching exercise and Hold-Relax PNF is 3.33, To find significant Mean difference for enhanced flexibility, Independent `t`-test was computed and obtained `t`(36) = 05.00 is found to be significant at 0.05 level of significance, as computed `t` value is higher than table Value (2.04) indicating Null Hypothesis is rejected implying there is significant difference between two interventions. As the Mean of Hold-Relax PNF Exercise has a higher mean than Dynamic stretching exercise, hence Hold-Relax PNF Exercise has a more pronounced effect than Dynamic stretching exercise in enhancing Flexibility among Wrestlers.

Table 9: Difference between hamstring flexibility of Group A and Group B of the right leg of knee extension ROM.

Knee Extension of Right Lower Limb	Mean	Mean difference	Standard Error Difference	Independent't' test	P-Value
Dynamic Stretching Exercise	8.88	1.22	0.376	03.231	0.0001
Hold-Relax PNF Exercise	7.66				

The data presented in table.no 9 shows the Mean difference between Dynamic stretching exercise and Hold-Relax PNF is 1.22, To find significant Mean difference for enhanced flexibility, Independent `t`-test was computed and obtained `t`(36) = 03.231 is found to be significant at 0.05 level of significance, as computed `t` value is higher than table Value (2.04) indicating Null Hypothesis is rejected implying there is significant difference between two interventions. Since the scoring pattern of Knee Extension is Negative, a lower score indicates healthiness. As the Mean of Hold-Relax PNF Exercise is lower than that of Dynamic stretching exercise, the Hold-Relax PNF Exercise has a more pronounced effect than Dynamic stretching exercise in enhancing Flexibility among Wrestlers.

Table 10: Difference between hamstring flexibility of Group A and Group B of Left Leg of knee extension ROM.

Knee Extension of Left Lower Limb	Mean	Mean difference	Standard Error Difference	Independent 't' test	P-Value
Dynamic Stretching Exercise	8.88	1.22	0.4033	03.030	0.00
Hold-Relax PNF Exercise	7.66				

The data presented in table 10 shows the Mean difference between Dynamic stretching exercise and Hold-Relax PNF is 1.22, To find significant Mean difference for enhanced flexibility, Independent `t`-test was computed and obtained `t`(36) = 03.030 is found to be significant at 0.05 level of significance, as computed `t` value is higher than table Value (2.04) indicating Null Hypothesis is rejected implying there is significant difference between two interventions. Since the scoring pattern of Knee Extension is Negative hence lesser the score indicates healthy and as the Mean of Hold-Relax PNF Exercise has lower mean than Dynamic stretching exercise, hence Hold-Relax PNF Exercise has pronounced effect than Dynamic stretching exercise in enhancing Flexibility among Wrestlers.

Discussion

The present study investigated the comparative effectiveness of dynamic stretching and hold–relax proprioceptive neuromuscular facilitation (PNF) stretching on hamstring flexibility among wrestlers. The results demonstrated that both interventions produced statistically significant improvements in hamstring flexibility, as evidenced by increases in 90–90 SLR and knee ROM within each group. However, intergroup comparisons revealed that hold–relax PNF stretching led to significantly greater improvements than dynamic stretching, indicating its superior efficacy in enhancing hamstring flexibility.

The significant improvements observed in the dynamic stretching group are consistent with existing literature highlighting the role of dynamic stretching in enhancing flexibility through increased muscle temperature, improved blood flow, and neuromuscular activation. Dynamic stretching facilitates movement through the full range of motion and reduces passive muscle stiffness, thereby improving functional flexibility. A recent systematic review reported that dynamic stretching is effective in improving hamstring range of motion, particularly in acute settings, and plays a crucial role in athletic warm-up routines.[6] These findings support the current results, where dynamic stretching produced meaningful improvements in SLR and knee ROM over a short intervention period.

In contrast, the hold–relax PNF group demonstrated greater improvements across all outcome measures. This superior effect may be explained by neurophysiological mechanisms such as autogenic inhibition and increased stretch tolerance. During the isometric contraction phase of PNF stretching, activation of Golgi tendon organs leads to reflex inhibition of the target muscle, allowing greater elongation during the subsequent stretch phase. Studies have consistently shown that PNF stretching yields greater gains in flexibility than other stretching techniques due to its combined mechanical and neural effects. For instance, recent research indicates that PNF stretching significantly improves hamstring flexibility and reduces muscle stiffness more effectively than other interventions.[7]

The intergroup differences observed in this study align with previous comparative research. A randomised controlled trial comparing different stretching approaches reported that techniques incorporating neuromuscular facilitation mechanisms, such as PNF, yield greater improvements in muscle extensibility than dynamic or conventional stretching methods.[8] Similarly, other studies have demonstrated that contract–relax techniques produce greater increases in ROM due to enhanced viscoelastic changes and improved tolerance to stretch.[9]

These findings corroborate the present study, in which PNF stretching resulted in significantly greater improvements in SLR and knee ROM than dynamic stretching.

Another important consideration is the duration of intervention. The current study employed a short-term (one-week) protocol, yet significant improvements were observed in both groups. Evidence suggests that even short-term stretching interventions can lead to measurable increases in flexibility; however, long-term interventions may produce more pronounced and sustained effects. Notably, while dynamic and static stretching may show similar short-term effects, repeated or prolonged stretching interventions tend to favour techniques that involve sustained or neuromuscular components, such as PNF.[6] From a clinical and sports performance perspective, these findings have practical implications. Dynamic stretching remains highly

relevant in pre-activity warm-up routines for its ability to enhance functional performance, neuromuscular readiness, and movement efficiency. On the other hand, hold–relax PNF stretching appears to be more effective when the primary goal is to achieve maximal improvements in muscle flexibility, particularly in rehabilitation or post-training settings. Therefore, integrating both techniques within a comprehensive training program may provide optimal benefits—dynamic stretching for performance preparation and PNF stretching for flexibility enhancement.

Despite the significant findings, certain limitations must be acknowledged. The sample size was relatively small, and the study duration was limited to one week, which limits the generalizability of findings regarding long-term effects. Additionally, the study focused exclusively on wrestlers, which may limit applicability to other athletic or non-athletic populations. Future research should explore larger sample sizes, longer intervention durations, and the inclusion of diverse populations to further validate and expand upon these findings.

Conclusion

Both stretching techniques are effective in improving hamstring flexibility in wrestlers, but Hold-Relax PNF stretching may offer a marginally better outcome. This finding supports the inclusion of both stretching methods in wrestling warm-up and rehabilitation routines to enhance flexibility and reduce the risk of injury.

Limitations

1. The sample size (n = 36) was relatively small, limiting the generalizability of the results.
2. The duration of intervention (1 week) was short; long-term intervention effects could not be assessed.
3. The study focused solely on wrestlers, so findings may not apply to other sports populations.
4. Gender distribution and training intensity levels were not equally controlled.
5. Only flexibility was measured; the study did not assess performance outcomes such as strength or agility.

Future Scope

1. Future studies should consider including a larger and more diverse sample population to enhance the external validity and generalizability of the findings.
2. Longer intervention durations and follow-up assessments are recommended to evaluate the long-term effectiveness and retention of flexibility gains.
3. Further research should incorporate additional outcome measures such as muscle strength, power, functional performance (e.g., sprinting, jumping), and injury incidence.
4. Comparative studies involving other stretching techniques (e.g., static stretching, ballistic stretching, and combined protocols) could provide a more comprehensive understanding of the most effective flexibility training strategies.
5. The use of more advanced and objective assessment tools, such as electromyography (EMG), ultrasound elastography, or motion analysis systems, is recommended.

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