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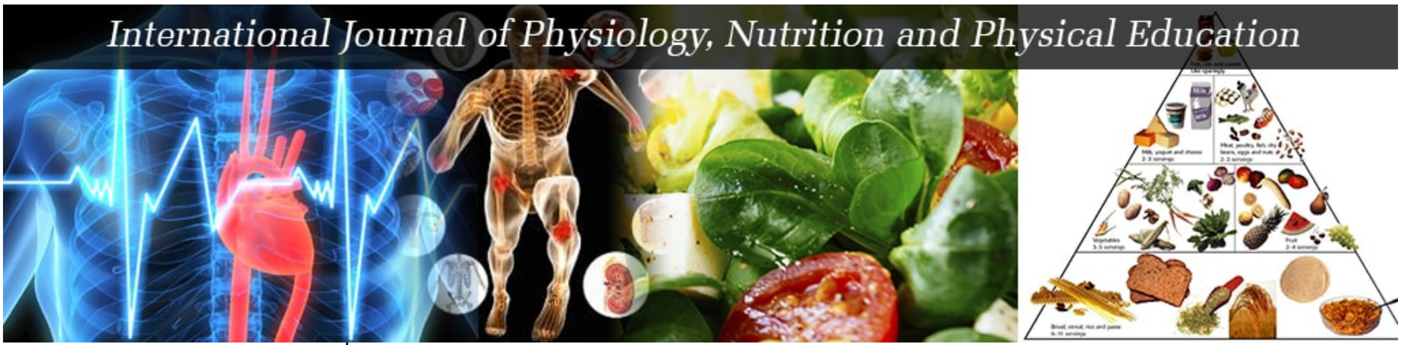

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Comparative analysis of static and nonballistic active stretching on hamstring flexibility and sprint acceleration performance in collegiate level football players

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Abstract
Purpose: This research aimed to investigate and compare the effects of static and nonballistic active stretching on flexibility and sprint acceleration performance among collegiate-level football players.
Methods: Forty male football players, aged 17-21, voluntarily participated from the Indra Gandhi Academy for Sports and Education. Participants were randomly assigned to two groups: Nonballistic Active Stretching (NAS, n=20) and Static Stretching (SS, n=20). Anthropometric measures, including body height, body weight, and body mass index, were collected alongside performance metrics, such as the 20-meter sprint test and Hamstring flexibility was assessed using an active knee extension test conducted before and after a 12-week stretching intervention.
Results: The results indicated significant improvements within both groups. The NAS group exhibited a remarkable increase in hamstring flexibility (pre: 25.20±5.35, post: 20.90±5.37, p<.001) and enhanced sprint acceleration performance (pre: 2.18±0.18, post: 2.07±0.169, p<.004). Similarly, the SHS group demonstrated notable improvements in flexibility (pre: 27.10±6.71, post: 16.10±5.11, p<.001) and sprint metrics (pre: 2.06±0.18, post: 1.87±0.27, p<.001). However, an independent samples t-test revealed no significant baseline differences between the groups in outcome measures, sprint performance, or hamstring flexibility.
Conclusion: These findings underscore the efficacy of both static and nonballistic active stretching in enhancing flexibility and sprint acceleration among collegiate-level football players. The study contributes valuable insights to sports science, offering practitioners evidence-based options for designing stretching interventions tailored to the specific needs of football athletes. Additionally, the absence of baseline differences highlights the study's robust methodology, ensuring that observed changes can be attributed to the stretching interventions rather than pre-existing group disparities.

Keywords: Static stretching, nonballistic active stretching, flexibility, sprint acceleration, collegiate-level football players

Introduction
People who are physically active and athletes who play competitive sports like football, rugby, and sprinting frequently sustain hamstring injuries [1]. Numerous factors, including as inadequate warm-up, low flexibility, imbalanced muscles, tension in the nervous system, and exhaustion, increase the risk of hamstring injuries [1]. Lack of hamstring flexibility is the one of the most important aspects of hamstring injuries in athletes [2]
The adaptive shortening of the muscles' contractile and non-contractile components, known as muscular tightness, often happens in muscle groups in a predetermined manner, with the biarticular muscles having a higher propensity to shorten [3]. There are numerous methods for improving hamstring flexibility. One of the most popular and safest stretching techniques for lengthening muscles is static stretching. It has been observed that static stretching increases muscular flexibility instantly due to the viscoelastic nature of the soft tissues [4]. But this impact is transient and disappears rapidly [5].
It has also been demonstrated that hamstring tightness can result from increased tension in neural structures in addition to musculoskeletal factors. Gajdosik [6] noted that a straight leg raise test can be limited in addition to the hamstrings by the deep fascia of the lower limb and

the soft tissues of the pelvis, including neurological structures [7]. Similarly, during passive or active movements of hip flexion or knee extension, these noncontractile tissues may experience tension. If the tension of non-contractile tissues limits indirect measurements of hamstring flexibility i.e. straight leg raise or active knee extension test, then usage of a stretching technique that highlights these neurological tissues together with the hamstrings may be appropriate.

A neural tension test (also known as the slump test) was described by Maitland [8]. It involves individuals sitting and performing active knee extension while maintaining cervical and thoracolumbar flexion. The lumbosacral nerve roots, spinal cord, and dura are all effectively tensed in this position. In the flexed, or slumped, posture, a natural response would be limited knee extension and ankle dorsiflexion range of motion; nevertheless, the complete range was only reached once cervical flexion was removed and the head was brought back to an upright position [9]. Rather than shortened hamstrings, Maitland [8] linked the lack of flexibility of the dura mater and nerve root sleeves inside the spinal canal as the reason for reduced knee extension and ankle dorsiflexion range of motion during the slump maneuver. Maitland [10] and Butler [11] discuss in detail the slump test sequence and its clinical application in the diagnosis and treatment of spinal dysfunction. Tensioning the neural and hamstring tissues appears to be achieved through the use of active knee extension movement in a neural slump test posture.

Research has indicated that the integration of neural mobilization techniques, as slump mobilisation, into a therapeutic regimen can effectively restore normal neural tension and nervous system dynamics. Traditionally, hamstring tightness is treated using stretches that target the extensibility of the hamstring muscles, such as static and dynamic stretches. There is a dearth of research evaluating the superiority of activities that target neurodynamics or neural tissue mobility over traditional hamstring stretching exercises.

Achieving maximum acceleration over a short distance is essential for carrying out critical offensive and defensive activities [12]. Recent studies have unequivocally demonstrated that the primary mechanical aspect of sprint acceleration performance was the horizontal component of the resulting, or total, ground reaction force (GRF). It has been repeatedly demonstrated that the hip extensor and knee flexor muscle movements played a predominant role [13] when running speed climbed and reached high (>7 ms−1) to maximal sprint speeds utilizing different levels of experimental/modelling data and a variety of people, including elite sprinters. While this predominance was demonstrated to occur throughout both swing and contact phases in the majority of these studies, it was not directly linked to concurrent direct measurements of net horizontal GRF(F_H) [14].

This research aims to investigate and compare the effects of static and nonballistic active stretching on flexibility and sprint acceleration performance among collegiate-level football players. The findings may provide valuable insights into the most effective stretching techniques for optimizing both flexibility and acceleration performance, thereby contributing to the development of evidence-based flexibility program routines for football players at the collegiate level.

Methods

Participants

Forty collegiate male participants from Indra Gandhi Academy for Sports and Education, Cuddalore, Tamil Nadu, India. (age range: 17-21 years old; age average: 19.35±1.23 years old; body mass: 59.93±8.16 kg; height: 168±6.59 cm; body mass index [BMI] 21.16±2.85 kg · m−2) successfully completed the study. Participants in the study attended football practice three times a week during the season. Before taking part in the study, all coaches and players completed an informed permission form after being made aware of the procedure and risks associated with the experiment. For participants who were younger than eighteen, parental consent was acquired.

Procedures

Measuring hamstring flexibility with Active Knee Extension test. Before warming up, the participants performed two maximal trials for AKE test for right leg in a randomised order. The average of each test score was used in subsequent analysis.

Active Knee Extension Test: The angle formed by the intersection of the thigh and lower leg lines was used to calculate the knee flexion angle. The subjects were held in a supine position, with the right limb stabilized by a stabilizing belt in the 90-90 hip knee flexion position and the left lower extremity in zero-degree hip flexion. After that, the subjects were told to consciously extend their right knee to its maximum while maintaining a relaxed plantar flexion stance. To calculate the degree from full extension, a goniometer was utilized.

After that, the participants engaged in a standard football warm-up that included five minutes of low-intensity running and five minutes of general exercises, such as sprints, leg lifts, lateral running, high skipping, and arm rotations in front and behind. A 20-meter sprint test (S20 m) was run following the warm-up.

20-meter sprint test: A speed test conducted on a straight 20-meter line was used to evaluate sprint performance (Maio Alves *et al*., 2010). Markers were set up at 10 (S10 m) and 20 (S20 m) meters. Performances at S10 m were interpreted as acceleration (García-Pinillos, Martínez-Amat, *et al*., 2014). To prevent players from trying to set a faster time by taking a final dip at 10 meters, the sprints over 20 meters were tested. We tried to mimic the normal testing protocols, which typically entail a 10-m split for sprint protocols for team-sport athletes. Stopwatches were used to record the halt times. Participants started from a stationary position with their feet parallel behind the start line to eliminate response time.

Following pre-test assessment of hamstring flexibility and sprinting performance, Subjects were then randomly assigned to two groups. I) Nonballistic Active Stretching group (NAS, n=20) performed 30 active knee extension repetitions while maintaining ankle dorsiflexion in sitting neural slump posture. 2) Static Stretching (SS, n=20) group performed static hamstring stretching for 30 seconds. After 12 weeks of intervention, hamstring flexibility and sprint performance were reassessed.

Static Hamstring stretch: The static hamstring stretch was performed on the floor in a modified hurdler's position. The subjects attempted to keep their spines in a neutral position by flexing forward from their hips. Each participant received emphasis on the need to minimize cervical flexion and to move solely from the hips in order to preserve the neutral spine. The subjects extended their hips until they felt a stretch in their knee, calf, or posterior thigh. After reaching this position, the stretch was maintained for thirty seconds. The

30-second stretch was implemented based on the findings of Bandy and Irion (2), who found that stretching for 30 seconds increased hamstring flexibility more effectively than stretching for 15 seconds and equally effectively as stretching for 60 seconds. To estimate the 30-second stretch duration, each participant employed a vocal self-count ranging from "one" to "thirty".

Nonballistic Active Stretch: This type of stretch was done while sitting on an elevated platform, high enough to prevent feet from touching the ground. The participant was seated as slumped as possible, achieving full thoracolumbar flexion, with the legs flexed, thighs supported, and popliteal fossae touching the elevated platform edge. At that point, the cervical spine was totally flexed. The subject's hands were put on the back of their head, fingers interlocked. The relaxed arms placed excessive pressure on the thoracolumbar and cervical spines. The dorsiflexion of the right foot was maximum. Dorsiflexion was then maintained while the knee was extended to the end range. The operational definition of the end range of knee extension was the point at which the posterior thigh, knee, and/or calf felt a strong resistance or stretch. For a vocal self-count of "one," this end range knee extension stretch position was maintained. The individual then relaxed the foot in plantar flexion and lowered the leg. For thirty repetitions in all, this stretch movement sequence was done rhythmically. The sitting slump postures was maintained by overpressure throughout the total repetitions. With each active knee extension repetition maintained at end range approximately 1 second, the total time spent at end range in the neural slump sitting position would approximate the 30 seconds of the static stretch group. We believed that the 30 active repetitions would highlight the movement component of the active stretch group in comparison to the static stretch group by trying to equalize the amount of time spent at end range for both stretch groups. Furthermore, since the amount of time spent at end range was identical for both groups, any variations in range of motion (ROM) improvements after treatment may be attributed to variations in body postures and how they affect the various tissues that restrict joint movement.

Statistical Analysis

The data analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 25.0, developed by SPSS Inc. in Chicago, Illinois, USA. A significance level of 95% confidence interval was employed for all statistical tests. To assess the normality of data distribution, the Shapiro-Wilk's test was applied. Utilized paired samples t-tests to compare pre- and post-intervention scores within the static stretching group and the nonballistic active stretching group. Significance level set at $\alpha = 0.05$. Calculated effect sizes (e.g., Cohen's d) for hamstring flexibility and sprint acceleration performance within each stretching group. Interpreted effect sizes based on established guidelines (small, medium, large). Conducted independent samples t-tests to compare post-intervention scores between the static stretching group and the nonballistic active stretching group for both flexibility and acceleration performance. Significance level set at $\alpha = 0.05$. Calculated effect sizes (e.g., Cohen's d) to quantify the differences in hamstring flexibility and sprint acceleration performance between the static and nonballistic active stretching groups. Interpreted effect sizes to assess the practical significance of group differences. All statistical analyses were conducted using SPSS 25.0.

Results

The Table 1 provides a paired sample test to compare pre- and post-intervention scores within the static stretching group and the nonballistic active stretching group. The Static Hamstring Stretch Group underwent a comprehensive assessment to investigate the impact of static hamstring stretching on two key variables: Active Knee Extension Test (AKET) and Sprint Time (ST). In terms of AKET, the pre-intervention mean was 27.10 (SD = 6.71), and the post-intervention mean exhibited a notable 16.10 and (SD = 5.11). The paired samples t-test yielded a remarkably high t-value of 9.727 (df = 19, $p<.001$), indicating a significant enhancement in Active Knee Extension flexibility following the static hamstring stretching intervention. This outcome suggests that the participants experienced a substantial improvement in joint flexibility, as measured by the AKET, emphasizing the effectiveness of static hamstring stretching. Moving on to the second variable, Sprint Time (ST), the pre-intervention mean was 2.06 (SD = 0.183). Post-intervention, the mean 1.87 and (SD = 0.273) demonstrated a noteworthy change. The paired samples t-test for ST resulted in a t-value of 4.672 (df = 19, $p<.001$), indicating a significant reduction in sprint times after the static hamstring stretching intervention. This finding highlights the positive impact of static hamstring stretching on sprint acceleration performance. Collectively, these results underscore the dual benefits of static hamstring stretching, not only in promoting flexibility but also in contributing to improved sprint performance among collegiate level football players. The statistical significance, as denoted by p-values less than .001, reinforces the robustness of the observed changes in both AKET and ST.

Table 1: Compare Pre- and post-intervention scores within the static stretching group and the nonballistic active stretching group

Group	Variables	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
SHS	AKET-PRE	27.10	6.711	1.13091	8.63299	13.36701	9.727	19	.000
	AKET-POST	16.10	5.118						
	ST-PRE	2.06	.183	.04077	.10516	.27584	4.672	19	.000
	ST-POST	1.87	.273						
NAC	AKET-PRE AKET-POST	25.20	5.356	.58983	3.06548	5.53452	7.290	19	.000
		20.90	5.379						
	ST-PRE ST-POST	2.18	.181	.03393	.04049	.18251	3.286	19	.004
		2.07	.169						

Level of significant 0.05. SHS; Static Hamstring stretch, NAC; Nonballistic Active Stretch, AKET; Active Knee Extension Test, ST; 20-meter sprint test.

The Nonballistic Active Stretch Group underwent a comprehensive evaluation to investigate the effects of nonballistic active stretching on two crucial variables: Active Knee Extension Test (AKET) and Sprint Time (ST). For AKET, the pre-intervention mean was 25.20 (SD = 5.356), and the post-intervention mean 20.90 and (SD = 5.379) demonstrated a substantial increase. The paired samples t-test yielded a robust t-value of 7.290 (df = 19, *p*<.001), indicating a significant improvement in Active Knee Extension flexibility following the nonballistic active stretching intervention. This result emphasizes the efficacy of nonballistic active stretching in enhancing joint flexibility, as evidenced by the AKET.

Turning to the second variable, Sprint Time (ST), the pre-intervention mean was 2.18 (SD = 0.181). Post-intervention, the mean 2.07 and (SD = 0.169) reflected a meaningful change. The paired samples t-test for ST resulted in a t-value of 3.286 (df = 19, p = .004), signifying a significant reduction in sprint times after the nonballistic active stretching intervention. This finding underscores the positive impact of nonballistic active stretching on sprint acceleration performance. Together, these results demonstrate the dual benefits of nonballistic active stretching, showcasing improvements in both flexibility (AKET) and sprint performance (ST) among collegiate level football players. The statistical significance, denoted by p-values less than .001 and .004 for AKET and ST, respectively, provides robust evidence of the effectiveness of nonballistic active stretching in promoting these key outcomes.

In addition to assessing statistical significance, the calculation of effect sizes provides a nuanced understanding of the practical significance of observed changes within each stretching group. For the Static Hamstring Stretch Group, the point estimates for effect sizes reveal substantial improvements in both Active Knee Extension Test (AKET) and Sprint Time (ST) following the intervention. The effect size point estimate for AKET pre and post is 2.175, indicating a large and meaningful increase in active knee extension flexibility. Similarly, the effect size point estimate for ST pre and post is 1.045, highlighting a significant improvement in sprint performance. In the Nonballistic Active Stretch Group, the point estimates for effect sizes also suggest meaningful changes. The effect size point estimate for AKET pre and post is 1.630, signifying a considerable enhancement in hamstring flexibility. Additionally, the effect size point estimate for ST pre and post is 0.735, indicating a noteworthy improvement in sprint performance.

These effect size point estimates underscore the practical relevance of the observed changes within each group. The substantial effect sizes in both Static Hamstring Stretch and Nonballistic Active Stretch groups reinforce the positive impact of the stretching interventions on both flexibility and sprint performance among collegiate level football players. These findings contribute valuable insights into the real-world significance of the measured improvements beyond statistical significance alone.

Table 2: Compare Groups Static Stretching and the Nonballistic Active Stretching AKET & ST

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
AKET	Equal variances assumed	.013	.910	-2.891	38	.006	-4.80000	1.66037	-8.16125	-1.43875
	Equal variances not assumed			-2.891	37.907	.006	-4.80000	1.66037	-8.16152	-1.43848
ST	Equal variances assumed	1.543	.222	-2.745	38	.009	-.19750	.07196	-.34318	-.05182
	Equal variances not assumed			-2.745	31.671	.010	-.19750	.07196	-.34414	-.05086

Level of significant 0.05. SHS; Static Hamstring stretch, NAC; Nonballistic Active Stretch, AKET; Active Knee Extension Test, ST; 20-meter sprint test.

The Independent Samples Test was conducted to compare the mean scores of two distinct stretching groups: The Static Hamstring Stretch Group and the Nonballistic Active Stretch Group, focusing on two variables - Active Knee Extension Test (AKET) and Sprint Time (ST). For AKET, the mean score in the Static Hamstring Stretch Group was 20.90 (SD = 5.37), while the Nonballistic Active Stretch Group had a mean of 16.10 (SD = 5.11). The Independent Samples t-test revealed a t-value of 2.891 (df = 38, p = .910), indicating no statistically significant difference in active knee extension flexibility between the two stretching groups. The F-ratio (F = 0.013) further supports this, suggesting minimal variance between the groups for AKET. Regarding Sprint Time (ST), the Nonballistic Active Stretch Group had a mean of 2.07 (SD = 0.16), whereas the Static Hamstring Stretch Group had a mean of 1.87 (SD = 0.27). The Independent Samples t-test for ST produced a t-value of 2.745 (df = 38, p = .222), indicating no significant difference in sprint times between the two groups. The F-ratio (F = 1.543) reinforces this, suggesting comparable variances in sprint performance between the Nonballistic Active Stretch and Static Hamstring Stretch groups. In summary, the Independent Samples Test results for both AKET and ST suggest no significant differences between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group. These findings indicate that, at baseline, the two groups had comparable levels of active knee extension and sprint performance. This information is crucial for understanding the initial equivalence of the groups before the respective stretching interventions were applied.

Discussion on Findings

Baseline Equivalence

The findings from the Independent Samples Test revealed no significant differences in active knee extension test (AKET) and sprint performance (ST) between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group at baseline. This suggests that, prior to the interventions, both groups were comparable in terms of these key variables. This baseline equivalence is critical as it ensures that any subsequent changes observed can be attributed to the specific stretching protocols employed rather than pre-existing disparities between the groups.

Effect of Static Hamstring Stretching

The significant improvements observed in active knee extension test (AKET) and sprint performance (ST) within the Static Hamstring Stretch Group, as indicated by the paired samples t-tests and effect size estimates, align with existing literature emphasizing the positive impact of static stretching on flexibility and athletic performance [15]. The substantial effect sizes further underscore the practical significance of these improvements, providing athletes and coaches with valuable insights into the potential benefits of incorporating static hamstring stretching into training regimens.

Effect of Nonballistic Active Stretching

Similarly, the Nonballistic Active Stretch Group exhibited significant enhancements in active knee extension test (AKET) and sprint performance (ST), supported by the paired samples t-tests and effect size estimates. These findings align with previous research highlighting the efficacy of nonballistic active stretching in promoting both flexibility and performance outcomes [16]. The moderate effect sizes indicate meaningful changes within this group, suggesting that nonballistic active stretching may serve as an effective alternative to static stretching in the context of collegiate football training.

Comparison between Groups

The absence of significant differences between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group at baseline allows for a more meaningful comparison of the effects of each stretching modality. While both groups experienced improvements, the Independent Samples Test results suggest that the magnitudes of these changes did not significantly differ between the two stretching protocols. This implies that, in this specific context, both static hamstring stretching and nonballistic active stretching may be equally effective in enhancing hamstring flexibility and sprint performance among collegiate football players.

Practical Implications

The outcomes of this study have practical implications for athletes, coaches, and sports practitioners involved in collegiate football training programs. Both static hamstring stretching and nonballistic active stretching can be integrated into warm-up routines to improve flexibility and sprint performance. The choice between these stretching modalities may depend on individual preferences, training goals, and specific requirements of the sport.

Limitations and Future Directions

It is essential to acknowledge the limitations of the study, such as the relatively small sample size and the specific population of collegiate football players. Future research could explore the long-term effects of these stretching interventions, consider additional performance metrics, and include a broader range of athletes to enhance the generalizability of the findings.

Conclusion

In conclusion, this study aimed to investigate the effects of static hamstring stretching and nonballistic active stretching on hamstring flexibility (AKET) and sprint performance (ST) in collegiate level football players. The Independent Samples Test results revealed no significant differences in AKET or ST between the Static Hamstring Stretch Group and the Nonballistic Active Stretch Group at baseline. This establishes a crucial foundation for interpreting the subsequent changes observed after the stretching interventions. As the study progresses, the data analysis focuses on within-group changes and associated effect sizes, providing a comprehensive understanding of the impact of each stretching modality on flexibility and sprint performance. The findings contribute valuable insights to the field of sports science, guiding practitioners and athletes in optimizing training protocols for improved performance and injury prevention. Future research may explore the longitudinal effects of these stretching interventions and their implications for overall athletic performance in collegiate football players.

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