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Nordic Exercise Versus Hold-Relax Stretching for Hamstring Flexibility in Soccer Players

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Abstract
Background: Reduced hamstring flexibility may impair movement performance and increase susceptibility to hamstring-related problems in soccer players. Nordic Exercise and Hold-Relax Stretching are commonly used to improve hamstring flexibility, but comparative evidence remains limited.
Objective: To evaluate the effects of Nordic Exercise and Hold-Relax Stretching on hamstring flexibility and compare their effectiveness in young soccer players.
Methods: This quasi-experimental pretest-posttest nonrandomized study involved 14 male soccer players aged 18–23 years with reduced hamstring flexibility. Thirty players were screened, and 14 eligible participants were allocated to either a Nordic Exercise group (n=7) or a Hold-Relax Stretching group (n=7). Both interventions were performed three times weekly for four weeks. Hamstring flexibility was assessed using the Active Knee Extension (AKE) test. Paired-sample t-tests were used for within-group comparisons, and independent-sample t-tests were used for between-group comparisons.
Results: Nordic Exercise significantly improved hamstring flexibility, with mean AKE scores decreasing from 37.86±6.96° to 27.86±5.96° (mean change=9.71±7.91°; p=0.016), representing a 25.6% improvement. Hold-Relax Stretching also significantly improved hamstring flexibility, with mean AKE scores decreasing from 39.71±6.49° to 32.00±5.13° (mean change=7.71°; p<0.001), representing a 19.4% improvement. Post-intervention AKE scores were lower in the Nordic Exercise group than in the Hold-Relax Stretching group (27.85±5.95° vs 32.00±5.13°), although the difference was not statistically significant (p=0.189).
Conclusion: Both Nordic Exercise and Hold-Relax Stretching significantly improved hamstring flexibility in young soccer players. Neither intervention demonstrated superior effectiveness during the four-week intervention period.

Keywords
Hamstring Muscles; Soccer; Exercise Therapy; Muscle Stretching Exercises; Range of Motion, Articular

Introduction

Soccer is a high-intensity intermittent sport that requires players to perform repeated sprinting, kicking, jumping, acceleration, deceleration, and rapid changes of direction throughout training and competition. These activities place substantial mechanical demands on the lower extremities, particularly the hamstring muscle group, which plays a critical role in hip extension, knee flexion, and dynamic stabilization during locomotor tasks. Consequently, hamstring-related disorders remain among the most common musculoskeletal problems encountered in soccer players and continue to represent a significant challenge for athlete performance and availability.[1,2]

Recent epidemiological studies have reported that hamstring injuries account for approximately 20–25% of all injuries sustained by professional soccer players and continue to increase despite advances in sports medicine and injury-prevention strategies.[1,2] Similar trends have been reported in various athletic populations, indicating that hamstring dysfunction remains a persistent concern in competitive sports.[3] In addition to causing time-loss from training and competition, hamstring injuries contribute to decreased performance, increased medical costs, and elevated risk of recurrent injury.[2] These findings highlight the importance of identifying modifiable risk factors associated with hamstring dysfunction and implementing effective preventive and rehabilitative interventions.

Among the modifiable factors associated with hamstring dysfunction, reduced hamstring flexibility has received considerable attention. Hamstring flexibility refers to the ability of the hamstring muscle-tendon unit to elongate adequately during movement without excessive resistance or discomfort. Adequate flexibility contributes to optimal joint range of motion, efficient force transmission, and normal lower-extremity biomechanics during athletic activities. Conversely, limited flexibility may alter movement patterns, increase passive muscle stiffness, and elevate mechanical stress on musculoskeletal tissues.[4] Previous investigations have demonstrated that athletes with reduced hamstring flexibility may exhibit impaired functional performance and an increased susceptibility to hamstring-related injuries compared with those who maintain normal flexibility.[4,5]

The clinical importance of hamstring flexibility can also be explained through the Movement System framework proposed by the American Physical Therapy Association. According to this framework, efficient movement is produced through coordinated interactions among musculoskeletal, neuromuscular, cardiopulmonary, and metabolic systems.[6] Within this context, the hamstring muscles function not only as force generators but also as dynamic stabilizers that contribute to efficient lower-extremity movement. Reduced flexibility may disrupt this interaction, resulting in compensatory movement strategies, altered neuromuscular control, and decreased movement efficiency.[7] Therefore, interventions designed to improve hamstring flexibility represent an important component of sports physiotherapy and athlete conditioning programs.

Several exercise-based interventions have been developed to improve hamstring flexibility. One of the most widely studied approaches is Nordic Exercise, an eccentric strengthening exercise designed to increase hamstring capacity under lengthening conditions. Previous studies have demonstrated that Nordic Exercise improves eccentric hamstring strength, promotes favorable architectural adaptations, and contributes to reduced hamstring injury rates among athletes.[1,8] Structural adaptations induced by eccentric loading, particularly increased fascicle length and the addition of sarcomeres in series, may also enhance the extensibility of the hamstring muscle-tendon unit.[8,9] These adaptations provide a physiological rationale for expecting Nordic Exercise to improve hamstring flexibility in addition to strengthening performance.

Another commonly prescribed intervention is Hold-Relax Stretching, a proprioceptive neuromuscular facilitation (PNF) technique that combines isometric muscle contraction with passive stretching. Hold-Relax Stretching is believed to improve flexibility through autogenic inhibition mechanisms mediated by Golgi tendon organ activation, resulting in decreased resistance to stretch and increased range of motion.[10,11] Previous studies have reported significant improvements in hamstring flexibility following PNF-based interventions in both athletic and non-athletic populations.[12–14] Furthermore, repeated stretching may reduce passive muscle stiffness and increase stretch tolerance, thereby contributing to enhanced flexibility.[10]

Although Nordic Exercise and Hold-Relax Stretching have each demonstrated beneficial effects on hamstring flexibility, evidence directly comparing these interventions remains limited. Existing studies have often focused on different athletic populations, including recreationally active individuals and athletes from sports with distinct biomechanical demands.[12,13] Consequently, the relative effectiveness of these interventions in soccer players remains unclear. Furthermore, previous studies have generally examined flexibility outcomes without adequately considering the different physiological mechanisms through which eccentric training and PNF stretching may influence hamstring extensibility. This limitation creates an important gap in the current literature.

Preliminary screening conducted among players of Mataram Utama Football Club identified several athletes with reduced hamstring flexibility based on Active Knee Extension (AKE) measurements. These findings suggest that hamstring tightness remains a relevant issue within this population and support the need for evidence-based interventions targeting flexibility improvement.[15,16] Determining whether Nordic Exercise or Hold-Relax Stretching provides greater benefits may assist physiotherapists, athletic trainers, and strength and conditioning professionals in selecting appropriate interventions for soccer players.

Therefore, this study aimed to investigate the effects of Nordic Exercise and Hold-Relax Stretching on hamstring flexibility among soccer players aged 18–23 years and to compare the effectiveness of both interventions. It was hypothesized that both interventions would significantly improve hamstring flexibility, with Nordic Exercise producing greater improvements because of the structural adaptations associated with eccentric training.[8,9]

Methods

This study employed a quasi-experimental pretest-posttest nonrandomized design to evaluate the effects of Nordic Exercise and Hold-Relax Stretching on hamstring flexibility in young soccer players. A quasi-experimental approach was selected because participant allocation was conducted within an existing team setting, making random assignment impractical while maintaining ecological validity in a real-world sports environment. The study was conducted between October 2025 and January 2026 at Mataram Utama Football Club, Yogyakarta, Indonesia.

Participants were recruited from active male soccer players registered at Mataram Utama Football Club. Recruitment was conducted through coordination with club management and coaching staff. A total of 30 players were screened for eligibility using the Active Knee Extension (AKE) test. Fourteen players met the eligibility criteria and agreed to participate, while 16 players were excluded because they did not meet the inclusion criteria.

The eligibility criteria included: (1) male soccer players aged 18–23 years; (2) active participation in regular soccer training; (3) reduced hamstring flexibility identified through AKE assessment; and (4) willingness to participate in the study. Exclusion criteria were: (1) history of hamstring injury within the previous six months; (2) musculoskeletal disorders affecting the lower extremities; (3) neurological conditions affecting movement performance; (4) participation in another flexibility training program during the study period; and (5) inability to complete the intervention protocol.

The minimum sample size was estimated using G*Power software with a significance level of 0.05 and statistical power of 80%, based on previous studies evaluating hamstring flexibility interventions. The final sample consisted of 14 eligible participants who completed all study procedures.[17]

Participants were assigned into two intervention groups using a nonrandomized assignment procedure based on training schedules and participant availability. Seven participants were allocated to the Nordic Exercise group and seven participants to the Hold-Relax Stretching group. To reduce selection bias, eligibility screening was completed before group allocation and identical inclusion and exclusion criteria were applied to all participants.

Hamstring flexibility was assessed using the Active Knee Extension (AKE) test, a valid and reliable method for evaluating hamstring extensibility. Previous studies have reported excellent reliability for the AKE test, with intra-rater reliability ranging from 0.78 to 0.94 and inter-rater reliability ranging from 0.98 to 0.99.11,22 During testing, participants were positioned supine with the hip flexed to 90° while the contralateral limb was stabilized. Participants were instructed to actively extend the knee to the maximum tolerable range without pain. Knee extension angle was measured using a universal goniometer. Lower AKE values indicated greater hamstring flexibility.

All assessments were performed before and after the four-week intervention period by the same trained assessor. The assessor was blinded to participant group allocation to minimize measurement bias. Participants allocated to the Nordic Exercise group performed supervised eccentric hamstring training three times per week for four consecutive weeks, resulting in a total of 12 training sessions. During the exercise, participants knelt on a padded surface with both ankles stabilized by a partner. Participants gradually leaned forward while resisting trunk descent through eccentric hamstring contraction until control could no longer be maintained, after which the hands were used to absorb the fall and assist return to the starting position.

The exercise dosage was progressively increased throughout the intervention period. During week 1, participants performed two sets of 6–8 repetitions. During week 2, the dosage increased to two sets of 8–10 repetitions. During week 3, participants completed three sets of 6–8 repetitions, while during week 4 they performed three sets of 8–10 repetitions. Rest intervals of three minutes were provided between sets. This progressive protocol was designed to facilitate adaptation, improve eccentric control, and promote structural changes within the hamstring musculature.[1,8]

Participants allocated to the Hold-Relax Stretching group performed a proprioceptive neuromuscular facilitation stretching protocol three times weekly for four weeks. The procedure began with passive stretching of the hamstring muscle to the point of mild discomfort, followed by an isometric contraction maintained for 6–10 seconds at approximately 50–70% of maximal effort against therapist resistance. Participants then relaxed for 2–3 seconds before a further passive stretch was applied and maintained for 10–15 seconds. The entire contraction-relaxation-stretch cycle was repeated three to five times during each session. This protocol was selected because it utilizes autogenic inhibition mechanisms that facilitate increased muscle extensibility following isometric contraction.[10,11]

All intervention sessions were supervised by a physiotherapist to ensure protocol consistency and participant safety. During the study period, participants continued their routine soccer training program provided by the club. No additional flexibility intervention programs were permitted. All participants completed the intervention and post-intervention assessment. No adverse events, injuries, or intervention-related complications were reported during the study period.

Data were analyzed using IBM SPSS Statistics. Continuous variables were presented as mean ± standard deviation (SD). The unit of analysis was the individual participant. Data normality and homogeneity assumptions were evaluated before hypothesis testing. Within-group differences between pre-intervention and post-intervention AKE scores were analyzed using paired-sample t-tests. Between-group differences were analyzed using independent-sample t-tests. Statistical significance was established at $p < 0.05$. This study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to data collection. Participant confidentiality and anonymity were maintained throughout the study.

Results

A total of 30 soccer players were screened for eligibility. Sixteen players were excluded because they did not meet the inclusion criteria, while 14 eligible participants were enrolled and completed the study. Participants were allocated into two intervention groups consisting of seven participants in the Nordic Exercise group and seven participants in the Hold-Relax Stretching group. No participants withdrew during the intervention period, and all participants completed both pre-intervention and post-intervention assessments.

The participant flow from eligibility assessment to final analysis is presented in Figure 1. Of the 30 participants assessed for eligibility, 16 were excluded because they did not meet the inclusion criteria. No participants declined participation or were excluded for other reasons. The remaining 14 participants were allocated equally to the Nordic Exercise group (n = 7) and the Hold-Relax Stretching group (n = 7). All participants received the assigned intervention, no participants were lost to follow-up, and all 14 participants were included in the final analysis.

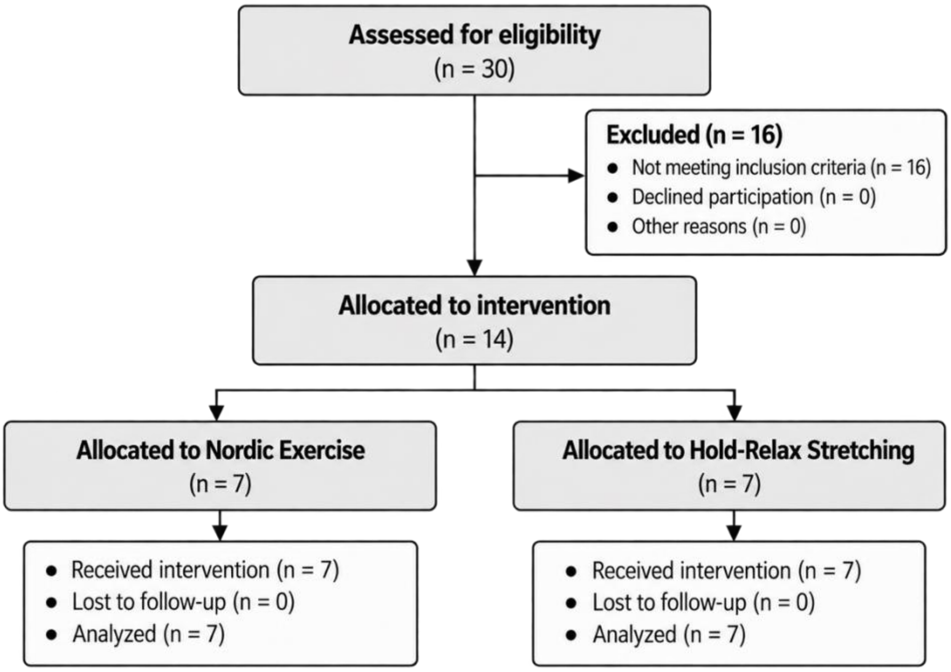

Figure 1. Participant Flow and Group Allocation

To evaluate the effectiveness of Nordic Exercise, hamstring flexibility was measured before and after the four-week intervention period using the Active Knee Extension (AKE) test. Descriptive statistics for the Nordic Exercise group are presented in Table 1.

Table 1. Hamstring Flexibility Before and After Nordic Exercise

Variable	n	Minimum	Maximum	Mean ± SD
Pre-test	7	30	45	37.86 ± 6.96
Post-test	7	20	38	27.86 ± 5.96
Change Score (Δ)	7	2	25	9.71 ± 7.91

As presented in Table 1, participants who performed Nordic Exercise demonstrated improved hamstring flexibility following the intervention. The mean AKE score decreased by 9.71°, representing an improvement of approximately 25.6% relative to baseline values. Because lower AKE values indicate greater hamstring extensibility, this reduction reflects a meaningful increase in flexibility after four weeks of eccentric training.

To determine whether the observed change was statistically significant, paired-sample t-test analysis was conducted. The results are summarized in Table 2.

Table 2. Within-Group Changes Following Nordic Exercise

Variable	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	p-value
Nordic Exercise	37.86 ± 6.96	27.86 ± 5.96	9.71	0.016

The analysis demonstrated a statistically significant improvement in hamstring flexibility following Nordic Exercise ($p = 0.016$), indicating that the intervention effectively increased hamstring extensibility during the study period. The effects of Hold-Relax

Stretching were subsequently evaluated using the same outcome measure. Descriptive statistics for this group are presented in Table 3.

Table 3. Hamstring Flexibility Before and After Hold-Relax Stretching

Variable	n	Mean ± SD
Pre-test	7	39.71 ± 6.49
Post-test	7	32.00 ± 5.13
Change Score (Δ)	7	7.71

Participants who received Hold-Relax Stretching also demonstrated improved hamstring flexibility following the intervention. Mean AKE scores decreased from 39.71° at baseline to 32.00° after treatment, corresponding to an average improvement of 7.71° or approximately 19.4%. To evaluate the statistical significance of these changes, paired-sample t-test analysis was performed. The results are presented in Table 4.

Table 4. Within-Group Changes Following Hold-Relax Stretching

Variable	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	p-value
Hold-Relax Stretching	39.71 ± 6.49	32.00 ± 5.13	7.71	<0.001

The results demonstrated a statistically significant increase in hamstring flexibility following Hold-Relax Stretching ($p < 0.001$), indicating that the intervention was effective in improving hamstring extensibility among the participating soccer players.
To address the primary objective of the study, post-intervention outcomes were compared between groups to determine whether one intervention produced greater improvements than the other. Comparative results are presented in Table 5.

Table 5. Between-Group Comparison of Post-Intervention Hamstring Flexibility

Variable	Nordic Exercise (n = 7)	Hold-Relax Stretching (n = 7)	p-value
Post-test AKE Score (Mean ± SD)	27.85 ± 5.95	32.00 ± 5.13	0.189

As shown in Table 5, participants in the Nordic Exercise group achieved lower post-intervention AKE scores than those in the Hold-Relax Stretching group, indicating a greater numerical improvement in hamstring flexibility. However, independent-sample t-test analysis demonstrated that the difference between groups was not statistically significant ($p = 0.189$). Therefore, although both interventions significantly improved hamstring flexibility, neither Nordic Exercise nor Hold-Relax Stretching demonstrated superior effectiveness within the four-week intervention period.

Overall, the findings indicate that both intervention approaches were effective for improving hamstring flexibility in young soccer players. Nordic Exercise produced a slightly greater mean improvement than Hold-Relax Stretching, but the magnitude of this difference was insufficient to demonstrate statistical superiority between interventions.

Discussion

This study investigated the effects of Nordic Exercise and Hold-Relax Stretching on hamstring flexibility in soccer players aged 18–23 years and compared the effectiveness of both interventions. The findings demonstrated that both interventions significantly improved hamstring flexibility after four weeks of training. Participants in the Nordic Exercise group showed an average improvement of 9.71°, whereas those in the Hold-Relax Stretching group demonstrated an average improvement of 7.71°. Despite the greater numerical improvement observed in the Nordic Exercise group, the difference between interventions was not statistically significant. These findings suggest that imprwere associated with improved AKE scores'effective strategies for improving hamstring flexibility in young soccer players.

The significant improvement observed following Nordic Exercise may be explained by the physiological adaptations associated with eccentric training. Nordic Exercise requires the hamstring muscles to generate force while lengthening, exposing the muscle-tendon unit to substantial eccentric loading. Previous studies have shown that repeated eccentric contractions stimulate structural adaptations, including increased fascicle length and the addition of sarcomeres in series.[1,8] These adaptations may increase the capacity of the hamstring muscles to tolerate elongation, thereby improving flexibility. In addition, eccentric training has been associated with reduced passive muscle stiffness and improved neuromuscular control, both of which may contribute to the improvements in AKE scores observed in the present study.[9]

The magnitude of improvement identified in the Nordic Exercise group is consistent with previous findings demonstrating positive effects of eccentric hamstring training on flexibility outcomes. Presland et al. reported that Nordic Hamstring Exercise training produced meaningful architectural adaptations in the biceps femoris long head, particularly increases in fascicle length.[8] Similarly, Cuthbert et al. concluded that eccentric exercise can positively influence range of motion and flexibility through adaptations in muscle mechanical properties.[9] Because soccer players are frequently exposed to sprinting, acceleration, deceleration, and directional changes that impose high eccentric demands on the hamstring muscles, these adaptations may be particularly relevant to soccer-specific movement requirements.

Hold-Relax Stretching also resulted in a significant improvement in hamstring flexibility. This finding supports previous evidence indicating that proprioceptive neuromuscular facilitation (PNF) stretching techniques are effective for increasing range of motion and reducing muscle tightness.[10–14] Unlike Nordic Exercise, which primarily produces structural adaptations, Hold-Relax Stretching is believed to improve flexibility through neurophysiological mechanisms. During the isometric contraction phase, activation of Golgi tendon organs may facilitate autogenic inhibition, reducing muscle resistance to stretching and allowing greater elongation during the subsequent passive stretch phase.[10,11]

Another explanation for the observed improvement is increased stretch tolerance. Contemporary research suggests that gains in flexibility following stretching interventions may not be entirely attributable to changes in tissue extensibility but may also result from altered sensory perception and greater tolerance to stretching discomfort.[10] Consequently, participants may have been able to achieve larger movement amplitudes during post-intervention testing, contributing to the reduction in AKE scores. This mechanism may explain why significant flexibility gains were achieved despite the relatively short intervention period.

Although Nordic Exercise produced a larger mean improvement than Hold-Relax Stretching, no statistically significant difference was detected between groups. This finding suggests that the two interventions may improve hamstring flexibility through different physiological pathways while ultimately producing comparable functional outcomes. Nordic Exercise promotes flexibility through structural adaptations induced by eccentric loading, whereas Hold-Relax Stretching primarily affects neuromuscular regulation and stretch tolerance. Nevertheless, both mechanisms appear capable of increasing hamstring extensibility to a similar extent over a four-week intervention period.

Several factors may explain the absence of a statistically significant difference between groups. First, the intervention period may have been insufficient to fully capture the long-term structural adaptations associated with eccentric training. Changes in muscle architecture often develop progressively and may require longer exposure to training stimuli before meaningful differences become apparent.[8] Second, the sample size was relatively small, with only seven participants per group. Small samples reduce statistical power and increase the likelihood of Type II error, where a true difference between interventions may exist but remain undetected. Therefore, the non-significant between-group finding should be interpreted cautiously and confirmed through studies involving larger samples.

The findings of this study also have practical implications for sports physiotherapy and athlete conditioning. Because both interventions significantly improved hamstring flexibility, clinicians may select either approach according to the specific goals of the training or rehabilitation program. Nordic Exercise may be preferable when flexibility improvement is desired alongside eccentric hamstring strengthening, whereas Hold-Relax Stretching may be useful when the primary objective is flexibility enhancement through a stretching-based intervention. Consequently, intervention selection should be individualized according to athlete needs, training context, and available resources.

From a clinical perspective, both interventions produced improvements exceeding 7° in AKE scores. Although the clinical threshold for meaningful improvement in AKE remains variable across studies, these findings indicate a substantial enhancement in hamstring extensibility over a relatively short period.[18] Although performance outcomes were not directly evaluated in the present study. Nevertheless, improved hamstring flexibility may facilitate more efficient lower-extremity movement patterns during soccer-specific tasks, as hamstring stretching reliably increases hamstring range of motion.[19]

Several limitations should be acknowledged when interpreting these findings. First, the study employed a quasi-experimental design without random allocation, introducing the possibility of selection bias despite the application of identical eligibility criteria to all participants. Second, participants were recruited from a single soccer club, which limits external validity and reduces the generalizability of the findings to other athletic populations. Third, the sample size was relatively small, potentially limiting statistical power. Finally, the study focused exclusively on hamstring flexibility and did not evaluate other important outcomes such as eccentric strength, sprint performance, agility, muscle stiffness, or injury incidence. Future research should incorporate larger samples, randomized allocation procedures, longer intervention periods, and broader outcome measures to provide a more comprehensive understanding of the comparative effectiveness of these interventions.

Overall, the present findings indicate that Nordic Exercise and Hold-Relax Stretching are both effective interventions for improving hamstring flexibility in young soccer players. Although Nordic Exercise produced a greater numerical improvement, the absence of a statistically significant difference suggests that both interventions can be considered viable options for flexibility enhancement within soccer conditioning and physiotherapy programs.

Conclusion

This study demonstrated that both Nordic Exercise and Hold-Relax Stretching significantly improved hamstring flexibility in soccer players aged 18–23 years. Participants in both intervention groups showed meaningful reductions in Active Knee Extension (AKE) scores following four weeks of training, indicating increased hamstring extensibility after treatment.

Although the Nordic Exercise group demonstrated a greater numerical improvement in flexibility than the Hold-Relax Stretching group, the difference between interventions was not statistically significant. Therefore, neither intervention demonstrated superiority over the other under the conditions of the present study.

These findings suggest that both Nordic Exercise and Hold-Relax Stretching may be incorporated into flexibility training programs for young soccer players. Nordic Exercise may be selected when flexibility improvement is desired alongside eccentric hamstring strengthening, whereas Hold-Relax Stretching may be considered when flexibility enhancement is the primary objective.

Future studies should employ larger sample sizes, randomized allocation procedures, longer intervention durations, and additional outcome measures, including eccentric strength, sprint performance, agility, movement quality, and injury incidence, to further clarify the comparative effectiveness of these interventions in athletic populations.

Clinical Implications

The findings of this study provide practical evidence for physiotherapists, sports medicine practitioners, athletic trainers, and strength and conditioning professionals working with soccer players. Both Nordic Exercise and Hold-Relax Stretching can be implemented as low-cost and accessible interventions for improving hamstring flexibility within routine training programs.

Nordic Exercise may offer additional benefits because it combines flexibility improvement with eccentric hamstring loading, which is commonly incorporated into athletic conditioning programs. In contrast, Hold-Relax Stretching may represent a practical alternative when stretching-based interventions are preferred or when athletes are unable to tolerate higher mechanical loading. Therefore, intervention selection should be based on the athlete's individual needs, training objectives, and rehabilitation context.

Study Limitations

Several limitations should be considered when interpreting the results of this study. First, the quasi-experimental design did not employ random allocation, which may have introduced selection bias. Second, participants were recruited from a single soccer club, limiting the generalizability of the findings to broader athletic populations. Third, the sample size was relatively small, reducing statistical power and increasing the possibility of Type II error. Fourth, baseline demographic characteristics such as body mass index, playing position, and playing experience were not recorded, preventing a more comprehensive comparison between groups. Finally, the study focused exclusively on hamstring flexibility and did not assess other relevant outcomes such as eccentric muscle strength, sprint performance, agility, functional movement capacity, muscle stiffness, or injury occurrence. Accordingly, the findings should be interpreted within the context of these limitations and confirmed through larger, methodologically rigorous investigations.

Author Contributions

Nirmala Yanti Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing Original Draft, Visualization, Project Administration.

Muhamad Ali Jafar Supervision, Methodology, Validation, Writing Review and Editing, Resources.

Moh. Ali Imron Validation, Formal Analysis, Writing Review and Editing, Supervision.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest related to this study and its publication.

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Ethics Statement

Written informed consent was obtained from all participants before enrollment in the study. The research was conducted in accordance with the principles of the Declaration of Helsinki. Participant confidentiality, anonymity, voluntary participation, and data protection were maintained throughout the study. No formal ethics committee approval number was available for this research.

References

1. van Dyk N, Behan FP, Whiteley R. Including the Nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries: a systematic review and meta-analysis of 8459 athletes. Br J Sports Med. 2019;53(21):1362-1370.
2. Ekstrand J, Waldén M, Hägglund M. Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study. Br J Sports Med. 2016;50(12):731-737.
3. Silvers-Granelli HJ, Cohen M, Espregueira-Mendes J, Mandelbaum B. Hamstring muscle injury in the athlete: state of the art. J ISAKOS. 2021;6(3):170-181.
4. Sharma S, K P, S N. Impact of hamstring flexibility on functional performance of collegiate football players. Int J Yogic Hum Mov Sport Sci. 2022;7(1):83-86.
5. Timmins RG, Bourne MN, Shield AJ, Williams MD, Lorenzen C, Opar DA. Short biceps femoris fascicles and eccentric knee flexor weakness increase the risk of hamstring injury in elite football (soccer): a prospective cohort study. Br J Sports Med. 2016;50(24):1524-1535.
6. McClure P, Tevald M, Zarzycki R, Kantak S, Malloy P, Day K, et al. The 4-Element Movement System Model to guide physical therapist education, practice, and movement-related research. Phys Ther. 2021;101(3):pzab024.
7. Anthis M, Gourd S, Kim B, Ruddy JD, Whiteley R, Timmins R, et al. The Fragility Index of Risk Factors for Hamstring Injuries. J Orthop Sports Phys Ther. 2024;54(10):672-678.
8. Presland JD, Timmins RG, Bourne MN, Williams MD, Opar DA. The effect of Nordic hamstring exercise training volume on biceps femoris long head architectural adaptation. Scand J Med Sci Sports. 2018;28(7):1775-1783.
9. Ripley NJ, Cuthbert M, Comfort P, McMahon JJ. Effect of additional Nordic hamstring exercise or sprint training on the modifiable risk factors of hamstring strain injuries and performance. PLoS One. 2023;18(3):e0281966.
10. Konrad A, Tilp M, Nakamura M. A comparison of the effects of foam rolling and stretching on physical performance: a systematic review and meta-analysis. Front Physiol. 2021;12:720531.
11. Sato S, Kiyono R, Takahashi N, Yoshida T, Takeuchi K, Nakamura M. The acute and prolonged effects of 20-s static stretching on muscle strength and shear elastic modulus. PLoS One. 2020;15(2):e0228583.
12. Ahmed H, Iqbal A, Anwer S, Alghadir A. Effect of modified hold-relax stretching and static stretching on hamstring muscle flexibility. J Phys Ther Sci. 2015;27(2):535-538.
13. Freitas SR, Mendes B, Le Sant G, Andrade RJ, Nordez A, Milanovic Z. Can chronic stretching change the muscle-tendon mechanical properties? A review. Scand J Med Sci Sports. 2018;28(3):794-806.
14. Medeiros DM, Martini TF. Chronic effect of different types of stretching on ankle dorsiflexion range of motion: systematic review and meta-analysis. Foot (Edinb). 2018;34:28-35.
15. Neumann DA. Neumann's kinesiology of the musculoskeletal system. 4th ed. St Louis (MO): Elsevier; 2024.
16. Magee DJ, Manske RC. Orthopedic physical assessment. 7th ed. St Louis (MO): Elsevier; 2018.
17. Bulus M. Sample size determination and optimal design of randomized/non-equivalent pretest-posttest control-group designs. Adiyaman Univ J Educ Sci. 2021;11(1):48-69.
18. Lim W. Optimal cut-off values of the active knee extension test for diagnosing hamstring tightness. J Bodyw Mov Ther. 2024;40:1769-1773.
19. Medeiros DM, Cini A, Sbruzzi G, Lima CS. Influence of static stretching on hamstring flexibility in healthy young adults: systematic review and meta-analysis. Physiother Theory Pract. 2016;32(6):438-445.