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Original Research

Optimizing Athletic Performance with Neural Mobilization: A Comparative Study in Soccer Players

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Abstract

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Neural mobilization (NM) is an acute bout method that aims to directly or indirectly affect the mechanical and physiological properties of the nerve tissue or surrounding structures using manual techniques or exercises. This study aimed to evaluate the immediate effects of incorporating NM into warm-up routines on flexibility, balance, and performance compared with static stretching (SS) and dynamic stretching (DS). Thirty-six amateur soccer players aged 18–25 participated in a randomized controlled, assessor-blinded study. Participants sequentially performed a 5-minute standardized warm-up, group-specific acute bout (SS, DS, or NM), and a 5-minute cool-down. Pre- and post-test assessments consisted of the straight leg raise test (flexibility), Y balance test (balance), single-leg forward hop test (performance), T-test (agility), and BlazePod reaction time. All groups showed significant post-test improvements in flexibility, balance, and performance (all $p < 0.05$, $\eta^2 = 0.06–0.18$). The NM group demonstrated a greater reduction in agility T-test time ($p = 0.028$, $\eta^2 = 0.10$), while no significant agility changes were observed in the other groups ($p > 0.05$). Intergroup analysis revealed greater improvement in the anterior reach direction of the Y balance test for the NM group ($p = 0.038$, $\eta^2 = 0.19$). No significant group-by-time interaction was found ($p > 0.05$). These findings suggest that NM, by targeting the neural system rather than muscle tissue, may provide additional neuromechanical benefits and enhance balance performance during warm-up in soccer players.

Keywords: Body balance, sport, therapeutic exercise, injury prevention, reaction time

Introduction

Warm-up routines are widely recognised as an essential component of athletic preparation, directly influencing muscle strength, endurance, performance, adaptation and injury risk.[1] Of the commonly used methods, static stretching (SS) and dynamic stretching (DS) have been the subject of extensive study. SS involves holding end-range positions for 15–60 seconds, repeated 2–4 times, and has been shown to effectively increase flexibility and range of motion (ROM) with regular practice. It is most often recommended after exercise or during cool-down sessions to reduce stiffness.[2,3] However, when performed immediately before activity, static stretching can temporarily reduce neuromuscular activation and explosive performance despite improving flexibility and ROM. In contrast, dynamic stretching involves actively moving muscles and joints

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through their full ROM. Numerous studies have demonstrated the positive effects of dynamic stretching on performance and flexibility, likely due to enhanced circulation and increased muscle temperature.[2] Sport-specific dynamic warm-ups in particular are thought to elicit comprehensive physiological and neural preparatory responses in junior handball players.[4]

In recent years, neural mobilization (NM) has emerged as an alternative approach to improving flexibility and performance. NM is an acute bout method designed to restore the nervous system's adaptability to movement and posture. It influences the mechanical and physiological properties of nerve tissue and surrounding structures directly or indirectly through manual techniques or exercise.[5] Two primary techniques are typically employed: 'gliding', which involves lengthening the nerve at one joint while shortening it at another, and 'tension', which elongates the nerve across two joints simultaneously.[6] Gliding techniques are associated with greater nerve excursion, while tension techniques increase intraneural pressure.[7] Beyond mechanical effects, NM may induce complex neurophysiological changes, including improved nerve mobility, enhanced intraneural fluid distribution and pain reduction. These changes are attributed to alterations in the viscoelastic properties of neural tissue.[8]

Previous studies have investigated the effects of neural mobilization on various populations, reporting improvements in flexibility, reduced pain and enhanced functional performance. For instance, Neto et al demonstrated an increased joint range of motion in healthy adults following neural mobilization, while Castellote-Caballero et al observed enhanced neuromuscular efficiency and balance control in clinical and athletic populations, respectively.[9,10] Together, these findings suggest that neural mobilisation may positively influence neural and functional parameters alike, supporting its inclusion in warm-up routines.

While the precise biological mechanisms remain unclear, neurodynamic mobilisation has demonstrated efficacy in improving lower-extremity flexibility and function.[9] Given the importance of hamstring flexibility in enhancing performance and reducing injury risk in footballers, neurodynamic techniques are often used to reduce neural mechanosensitivity and increase functional capacity.

Unlike traditional stretching methods, which primarily target muscle tissue, NM focuses on neural structures. This suggests that integrating it into warm-up routines could influence athletic performance via different mechanisms. However, to our knowledge, no studies have directly compared the effects of SS, DS, and NM on athlete performance during the warm-up period. Therefore, this study investigated the effects of SS, DS and NM acute bouts integrated into the warm-up on flexibility and functional performance in amateur footballers. Based on prior evidence supporting the positive effects of NM, we hypothesized that including NM in warm-up training could serve as an alternative to conventional stretching methods and enhance flexibility and performance parameters such as balance, agility, reaction time and jumping skills.

Methods

Participants

This study was a 3-armed assessor-blinded randomized controlled trial with neural mobilization group (NMG), dynamic stretching group (DSG) and static stretching group (SSG). All exercises were performed under the supervision of a physiotherapist after a standardized warm-up period. Cool-down exercises were given to all participants after the acute bout. Participants were given standardized demonstrations and verbal feedback to ensure proper execution of stretching and neural mobilization techniques. None of the participants had previous experience with neural mobilization techniques. This study was approved by the Istanbul Medipol University Non-Interventional Clinical Studies Ethics Committee (approval number E-10840098-772.02-2026) and was conducted in accordance with the ethical principles set out in the Declaration of Helsinki.[11] Informed consent was obtained from all participants prior to their inclusion in the study. It was carried out in university settings between April 2023 and February 2024 and registered at ClinicalTrials.gov with the identifier NCT06298851.

A priori sample size calculation for both groups was performed using G*Power 3.1.9.7 and the following parameters taken from a previously published study: ANOVA - repeated measures, within-between interaction as the statistical test, an effect size of 0.42 (medium), an alpha of 5% and 95% power. It was estimated that a total of 27 participants were required.[12]

Participants were recruited from amateur soccer teams, and a total of 36 players aged between 18-25 who met our inclusion criteria were included in the study. These individuals were those who had not had any acute lower or upper extremity injuries, had not undergone any surgical intervention in the last 6 months, and had been playing amateur soccer regularly for at least 1 year. Those with orthopedic, neurological, rheumatological, or cardiovascular health problems that would prevent the application of the tests were not included in the study. Participants who also exhibited excessive muscle tightness or pain during the pre-assessment were not included in the study. Participants who reported previous mild injuries (e.g., minor ankle sprain) were further examined; if full functional recovery and symmetrical ROM were verified, they were allowed to participate. After determining their willingness to participate, individuals signed an informed consent form, their demographic information was recorded, and they were randomly divided into three groups: NMG, DSG, and SSG. Randomization was performed using sealed and sequentially numbered envelopes.

Protocol

Data were collected at baseline (T0) and post-test (T1), with assessments conducted 5 minutes after the acute bout by a blinded physiotherapist. Demographic variables including age (years), weight (kg), height (cm), body mass index (BMI)(kg/m^2) were documented prior to the assessment. The straight leg raising test was used to evaluate flexibility, the Y balance test was used for balance, the single leg hop test was used for functionality, the T test was used for agility, and the Blaze Pod Reaction Time Determination Test was used for determining reaction time.

Straight Leg Raise Test (SLR).

The SLR test is a widely used clinical tool to assess changes in hamstring flexibility. During the test, the lateral condyle of the femur, the fibular head, and the fibular malleolus were determined as anatomical reference points while the participant was lying in the supine position. The axis of the goniometer was placed over the greater trochanter of the femur, and the knee and ankle were held in extension. Hip flexion was increased by stabilizing the talus and not rotating the hip. The participants' lower extremities were raised until pain was felt in the posterior thigh region, while care was taken to ensure that the knees were not bent and the pelvis was not in retroversion. One arm of the goniometer was aligned parallel to the table, and the other arm was aligned along the line between the fibular head and the malleolus. Finally, the angle between the arms of the goniometer was measured and recorded.[13] For the purposes of this study, the SLR measurement was taken from the dominant lower extremity and used for statistical analysis.

Y Balance Test.

Participants were asked to stand on one leg on the footplate in the middle of the Y Balance Test area, reach as far as possible with their other leg, and return to the starting position without losing their balance. The test was performed with three trials for both lower extremities, and the participants were aimed to reach the maximum reach distance in the anterior, posteromedial, and posterolateral directions. The maximum distances reached in each trial were recorded.[14]

Single leg hop test.

For the test, a 2-meter tape measure was attached horizontally to a flat surface. Participants were asked to stand on one leg with their hands on their waist, with their fingertips remaining at the zero value of the tape measure, and to jump forward as much as possible and land on the same foot. The distance at which the fingertip first touched the ground after jumping was recorded. After landing, participants were asked to maintain the same position for 2 seconds. After the trial application, 3 test repetitions were performed at 30-second intervals and the best result was recorded in centimeters. The SLHT was also performed on the dominant lower extremity.[15]

T Test.

This test involves four contact points arranged in a T shape in an area 10 meters long and 10 meters wide. Participants are asked to complete a specified series by moving in different directions and shapes between these contact points in the shortest possible time. The participant must always look in the same direction during the test. The movements are performed by stepping forward, backward, right and left. In total, a distance of 40 meters is completed by stepping 10 meters forward, 10 meters right, 10 meters left and 10 meters back.[16]

BlazePod Reaction Time Test.

The BlazePod system equipped with touch sensors and LED lights was used to evaluate reaction time, instantaneous speed, and reflexes. For the lower extremity assessment, four BlazePod sensors were positioned on the floor in a square arrangement, with each sensor placed 1 metre apart from the next. Participants were instructed to stand at the centre of the square on a designated spot, maintaining a ready stance with their weight distributed evenly. During the experimental procedure, when one of the sensors illuminated randomly, the participant was instructed to touch the illuminated sensor as quickly as possible using their foot. Participants performed two trials with 3-minute rest periods. During the evaluation, the total number of touches made in 15 seconds, the visual response time (ms) per touch, and the average response time were analyzed[17] (Figure 1).

Figure 1. Reaction time measurement with BlazePod

Participants sequentially performed warm-up, acute bout, and cool-down exercises. After the warm-up exercises, participants performed SS, DS, or NM acute bouts based on the groups they were assigned to, followed by cool-down exercises. The warm-up and cool down exercises were performed for 5 minutes and participants completed a football-specific submaximal running program that includes vertical jumping, sprinting, and joint mobility exercises. There were 10-minute rest intervals included between the warm-up activities and the subsequent tests to limit the effects of fatigue.

Participants in the NMG group performed nerve gliding techniques of peroneal, femoral, and sciatic nerves (Figure 2). All slides were performed in 4 sets of 10 repetitions for each limb, with each slide cycle lasting 6 seconds. A 1-minute rest period was given between sets for both limbs. A metronome set at 10 BPM was used to ensure accurate timing of the exercises[12]. The application was carefully monitored by the supervising physiotherapist, and participants were instructed to move until they felt a mild stretching or sliding sensation—without any pain, numbness, or tingling. Before the acute bout phase, all participants received visual demonstrations and detailed verbal explanations, followed by 2–3 familiarization trials to ensure they could clearly distinguish between normal neural movement and discomfort.

Femoral nerve gliding.

Mobilization of the femoral nerve was performed with participants in a prone position and hip hyperextension. Tension was achieved by placing the knee in a fully flexed position and the ankle in plantar flexion (Figure 2a).

Sciatic nerve gliding.

The subjects performed the mobilization in a sitting position with the trunk in thoracic flexion, alternating movements: Cervical extension with knee extension and ankle dorsiflexion (Figure 2b), and cervical flexion with knee flexion and ankle plantar flexion (Figure 2c). Tension was provided by flexing the hip and dorsiflexing the ankle to the point where stress was felt.

Peroneal nerve gliding.

A gliding movement targeting the peroneal nerve was initiated from a starting position consisting of ankle dorsiflexion, knee and hip extension. Participants plantar flexed and inverted their ankles, lowered their knees to full flexion and hips to 90 degrees, and then returned to their starting positions[16] (Figure 2d).

Figure 2. Lower extremity neural mobilization applications: (a) femoral nerve gliding; (b) initial position of sciatic nerve gliding; (c) end position of sciatic nerve gliding; (d) peroneal nerve gliding.

Table 1. Dynamic stretching exercises for participants in the DSG.

Number	Exercise
1	Walking on toes
2	Lunges on right/left knee
3	Lateral walking with the knee flexed to 90°
4	Marching high knees exercise
5	Jogging and 90° forward flexion of the right/left hip
6	Jogging and right/left hip adduction (with knee flexed at 90°)

Participants in the DSG performed 6 different dynamic stretching exercises for the lower extremities. Exercises for this group consisted of functional activities that included dynamic stretching of the hamstrings, quadriceps, hip flexors, extensors, abductor and adductor muscles, and gastrocnemius muscles. All stretching movements were performed in two circuits in a 15 m^2 area. Each exercise cycle lasted 6 seconds, each set contained 10 repetitions, and a 1-minute rest period was given between sets. These procedures were repeated for both extremities[18] (Table 1).

In the SSG, stretching exercises were applied to the hamstrings, quadriceps, and gastrocnemius muscles for both extremities. Each exercise lasted 15 seconds, and was performed in 4 sets of 4 repetitions. A 1-minute rest period was given between sets[18] (Table 2).

Table 2. Static stretching exercises for participants in the SSG.

Number	Exercise
1	Standing quadriceps stretch: Stand erect, fold one knee and bring your heel toward your hip while holding your foot with one hand.
2	Modified hamstring stretch: In a sitting position with one leg straight, place your other foot on the inside of the straight leg and reach forward.
3	Gastrocnemius stretch: Standing with feet 60-90 cm away from the wall, lean against the wall with both hands, keeping your back leg straight and your front leg slightly bent.
4	Adductor stretch: Sit in a sitting position with an upright spine, bending your knees so that the soles of your feet touch each other and let your knees drop.
5	Lumbar stretch: In a sitting position, keep one leg straight and place the other foot on the outside of your straight leg and rotate the body to the diagonal side.

Statistical Analysis

Data were analyzed using IBM SPSS (Statistical Package for Social Science) 22.0 software. The significance level was previously set at "p" less than 0.05. Mean, minimum (Min), maximum (Max), frequency (n) and percentage (%) values were given from descriptive statistics. Shapiro-Wilk test and histogram plots were used to test the normal distribution. Between group differences for baseline characteristics were explored using a Kruskal Wallis Test. Initially, differences between T0 and T1 were calculated using the Wilcoxon Matched-Pairs Test. Between group differences for T1 parameters were calculated with Kruskal Wallis test. When a significant main effect for time was found, post hoc comparisons were made with the Mann Whitney-U test and Bonferroni correction was used. Subsequently, we performed a 3 (group)×2 (time) repeated measures ANOVA using baseline and post-evaluation measurements, with the group as the independent variable. A significant level was set at $p < 0.05$.

Results

The study was completed with a total of 36 individuals (NMG=12, DSG=13, SSG=11) between April 2023 to August 2024. The CONSORT flow diagram of the study was shown in Figure 3.

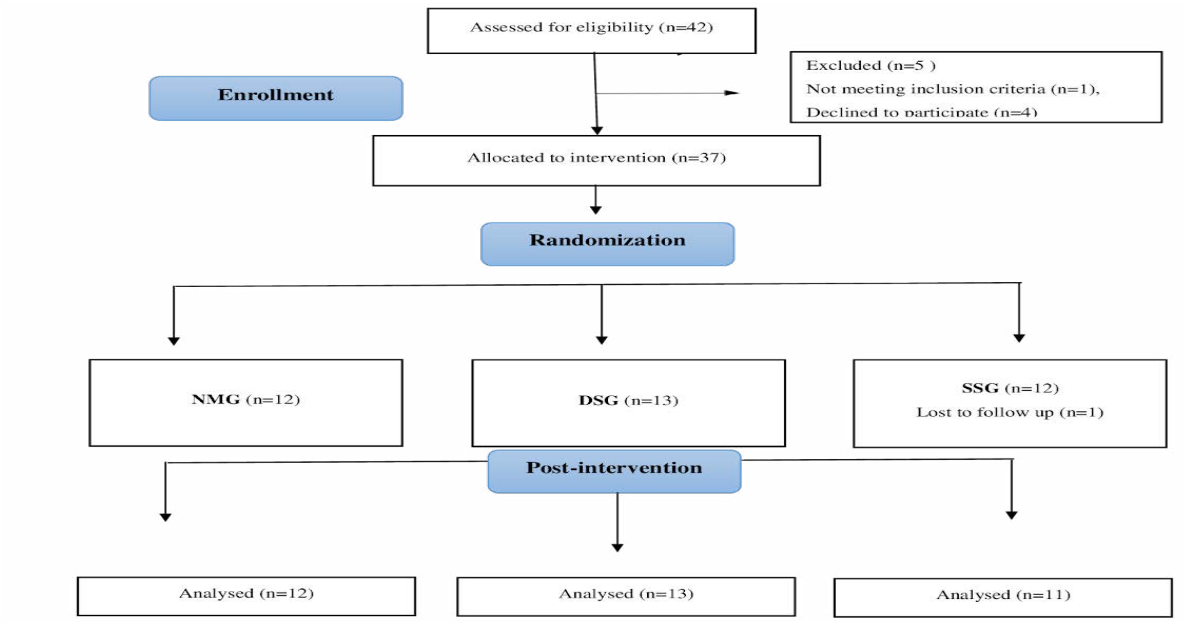

Figure 3. Flow diagram of this study

All baseline parameters were comparable between groups. A total of 36 participants (14 females and 22 males) were included in the analysis. There were no significant baseline between-group differences found in the line of participant characteristic (p>0.05) (Table 3).
Table 4 shows the statistical results of the effects of different acute bouts added to the warm-up period of amateur soccer players on muscle flexibility, balance, performance, agility and reaction time at the baseline (T0) and post-test (T1). Baseline scores of the groups were similar for all demographic and performance-related outcome measures (SLR, YBT-A, YBT-PM, YBT-PL, SLHT, T-test, and reaction time), with no significant between-group differences at T0 (all p>0.05; Table 4). Results for all participants, regardless of group distribution, flexibility, balance (Y balance test PM and PL measurement), functionality, and reaction time showed significant improvements over time (p<0.05). Anterior Y balance test results showed significant increments in NMG and DSG (p<0.05). Agility, measured by t-test, showed statistically better results over time in NMG (p<0.05). No significant between group differences were found at T1 except for Y-balance anterior assessment (p=0.038), which was higher in the NMG.

Table 3. Characteristics of participants

		NMG (n=12)		**DSG (n=13)**		**SSG (n=11)**		**p[a]**
Gender	**Male, n (%)**	7 (%58.3)		8 (%61.5)		7 (%63.6)		0.967
	Female, n (%)	5 (%41.7)		5 (%38.5)		4 (%36.4)		
		Mean (SD)	**min-max**	**Mean (SD)**	**min-max**	**Mean (SD)**	**min-max**	
Age (years)		22.08 (2.50)	18.00-26.00	22.15 (1.77)	20.00-25.00	22.45 (1.75)	20.00-26.00	0.888
Body height (cm)		170.92 (10.88)	152.00-188.00	173.08 (8.59)	156.00-182.00	171.09 (9.60)	158.00-182.00	0.754
Body mass (kg)		66.58 (12.12)	43.00-84.00	79.12 (19.07)	58.80-114.50	69.54 (13.95)	55.00-96.00	0.255
BMI (kg/m²)		22.59 (2.01)	17.67-24.81	26.57 (6.84)	18.52-40.09	23.56 (3.10)	20.96-30.30	0.593

Table 4. Outcomes comparison at baseline and post test

	Groups	T0 Mean (SD)	T1 Mean (SD)	p^b
SLR (°)	**NMG**	78.41 (4.81)	85.50 (6.49)	0.003*
	DSG	72.15 (6.59)	80.15 (7.82)	0.001*
	SSG	73.09 (12.56)	78.54 (12.26)	0.007*
	p^a	0.098	0.289	
	e^2	0.132	0.071	
YBT-A (cm)	**NMG**	69.00 (4.80)	75.25 (5.69)*	0.002*
	DSG	69.07 (5.63)	73.92 (7.09)	0.004*
	SSG	66.54 (7.78)	69.09 (7.75)	0.128
	p^a	0.421	0.038**	
	e^2	0.049	0.186	
YBT-PM (cm)	**NMG**	87.50 (8.0)	93.50 (7.60)	0.007*
	DSG	86.53 (11.46)	91.69 (11.96)	0.009*
	SSG	82.45 (13.62)	88.45 (12.36)	0.003*
	p^a	0.276	0.357	
	e^2	0.073	0.059	
YBT-PL (cm)	**NMG**	95.08 (4.14)	101.58 (5.63)	0.005*
	DSG	90.00 (12.34)	93.23 (11.97)	0.030*
	SSG	90.45 (9.22)	95.18 (9.47)	0.011*
	p^a	0.327	0.066	
	e^2	0.064	0.155	
SLHT (cm)	**NMG**	148.50 (15.85)	161.08 (19.48)	0.010*
	DSG	143.76 (27.58)	153.23 (26.9)	0.041*
	SSG	133.81 (18.99)	143.90 (26.85)	0.028*
	p^a	0.197	0.123	
	e^2	0.093	0.120	
T-Test (s)	**NMG**	15.86 (1.49)	14.89 (1.66)	0.028*
	DSG	15.99 (2.03)	15.56 (2.38)	0.087
	SSG	16.46 (1.90)	16.41 (2.17)	0.051
	p^a	0.811	0.525	
	e^2	0.012	0.037	
Reaction Time (s)	**NMG**	1680.83 (462.48)	1209.16 (403.46)	0.002*
	DSG	1830.00 (667.01)	1421.84 (481.57)	0.001*
	SSG	1787.18 (288.52)	1464.09 (420.73)	0.013*
	p^a	0.450	0.480	
	e^2	0.176	0.042	

Abbreviations: p^a, Kruskal Wallis Test; p^b, Wilcoxon Signed-Rank Test; e^2, Effect size of between-group; NMG, Neural Mobilization Group; DSG, Dynamic Stretching Group; SSG, Static Stretching Group; SLHT, Single Leg Hop Test; SLR, Straight Leg Raise; YBT-A, Y Balance Test- Anterior; YBT-PM, Y Balance Test- Posteromedial; YBT-PL, Y Balance Test- Posterolateral. *Within-group $p<0.05$, **Between-group $p<0.05$.

Discussion

In our study, we evaluated the immediate effects of NM and two different stretching techniques (dynamic and static) after the acute bout. The findings showed that all three applications had similar and positive effects in terms of improving flexibility, balance, performance and reaction time in amateur football players, and that the anterior measurement parameter of the balance test revealed better improvement in the neural mobilization group immediately after the acute bout.

It is known that participating in sports improves general health and reduces the risk of chronic diseases. As more people participate in sports, competition between individuals has increased, along with a focus on all aspects of warm-up and cool-down sessions to improve performance and reduce the risk of injury. It is very important to implement effective warm-up methods to achieve the desired results and prevent injuries. Traditionally, pre-activity warm-up includes static or dynamic stretching in addition to low-intensity aerobic exercise.[19] However, as far as we can find, there are few studies in the literature on the effects of neural mobilization techniques on athletic performance. Therefore, in this study, we investigated the effect of neural mobilization against static and dynamic stretching in amateur soccer players.

NM is distinct from both SS and DS insofar as it primarily targets the mobility and function of the nervous system as opposed to muscle tissue. By focusing on neural excursion, mechanosensitivity, and neurodynamic efficiency, it is hypothesised that neural mobilisation may enhance proprioceptive feedback and motor control.[20] The present findings suggest that incorporating neural mobilization into warm-up routines could provide an additional neuromechanical advantage, particularly in football players. Specifically, the greater improvement observed in the anterior reach direction of the Y-Balance Test indicates that neural mobilisation may facilitate movement control through distinct neural mechanisms. Therefore, the integration of neural mobilization into pre-activity warm-ups may present a complementary strategy to reduce the risk of injury and optimise sport-specific performance in football players.

Although previous studies have shown that SS and DS effectively increase flexibility, this is the first study to our knowledge that compares the effects of neural mobilization with static and dynamic stretching on flexibility.[21] A review reported that while a single session of DS and SS had similar short-term effects in improving hamstring flexibility, multiple sessions of SS could significantly increase hamstring length compared to DS.[22] However, it is known that neural gliding with 40 or 80 repetitions (4 and 8 sets of 10 repetitions) applied to the dominant lower extremity increases the performance of basketball players evaluated by single leg hop test and flexibility.[23] In our study, DS and SS provided similar improvements in flexibility, balance, function, agility and reaction time in single sessions, and repetitive neural gliding increased flexibility and performance in amateur soccer players after the acute bout. In a cross-sectional study involving 27 healthy college students, 5 minutes of neural gliding or dynamic stretching exercises were added to the warm-up period to monitor changes in hamstring flexibility and vertical jump testing over time. While no improvement was observed in vertical jump as a result of either acute bout, an increase in hamstring flexibility was found in both groups. As a result, it has been suggested that neural mobilization will not have any negative effects on athletic performance during warm-up and may improve flexibility.[24] Similar results were obtained with the increase in hamstring flexibility after NM applied to wrestlers and soccer players.[10,25] Castellote-Caballero et al. found that hamstring flexibility increased significantly in healthy young male soccer players after three sessions of sciatic nerve glide therapy applied for a week compared to the static stretching group.[10] In our study, although there was an increase in flexibility in the groups where NM, SS and DS were applied, no superiority was achieved between the acute bouts.

Hamstring injuries are one of the most common types of injuries in sports and have a high risk of recurrence. Studies have shown that the cause of hamstring injuries in football is generally related with weakness and flexibility limitation,[26,27] so this study focused on hamstring flexibility in amateur soccer players. Although previous studies have shown that hamstring flexibility increases with the mobilization of neural tissues, it remains unclear whether there is an increase in the mobility of neural.[13] However, it is thought that the increase in flexibility after NM occurs due to the increase in sciatic nerve mobility at the back of the thigh and the decrease in sensitivity.[28] Although there is not enough evidence, we think that the increase in hamstring flexibility in this study is a result of neural tissue mobility and this increase can be achieved by adding neural mobilization to the warm-up sessions before competitions in order to prevent injuries.

While several studies have shown detrimental effects of SS on muscle strength and performance,[3] other studies suggest that short-term SS under 90 seconds does not cause deterioration in performance[2]. Three sessions of DS applied to men with high physical activity levels increased vertical jump and sprint performance. DS has been suggested for use to help maintain or improve the performance outcome of physical activity, particularly in sprinting and jumping events. In another study, it was shown that the neural mobilization applied to soccer players improved the jump test and that the improvements continued until 30 minutes after the acute bout.[29] Similar to this study, the neural mobilization applied to amateur soccer players resulted in a similar improvement in jumping test results as SS and DS groups.

A study investigating the effect of static and dynamic stretching on agility performance in basketball players stated that dynamic stretching was more effective than static stretching.[30] In a study involving asymptomatic individuals but with a positive neural tissue tension test, an increase in strength and agility parameters was detected after NM and sham mobilization applied to the lower extremity, and the usability of neural tissue mobilization in increasing lower extremity agility was demonstrated.[31] In our study, consistent with the literature, an increase in agility parameters was observed only in the group that underwent neural tissue mobilization.

In the literature, there are studies on both patient and healthy populations with contradictory results showing that neural mobilization improves balance[32,33] and that it does not.[34] Our study concluded that all stretching methods improved balance acutely. However, there is no strong evidence that neuromobilization directly influences motor control in asymptomatic individuals, primarily because the number of studies investigating this relationship is limited.[33] Although football is a multidirectional sport, amateur training programs mostly emphasize forward movements and linear drills.[35] Therefore, it is possible that motor control ability is more developed in forward directions, and NM may enhance anterior balance performance by increasing proprioceptive input.

In addition to its potential effects on balance, neural mobilization may also influence neuromuscular coordination and reaction time. For example, the reaction times of asymptomatic, healthy volunteers have been evaluated with the Nelson Hand Reaction Test before and after median nerve mobilization, and a significant reduction in reaction time was observed following the acute bout.[36] This improvement can be explained by enhanced neuromuscular activation and motor learning mechanisms, which may partly support our findings related to functional performance improvements observed after NM-based warm-up routines.

Moreover, considering that neuromuscular activation and flexibility are closely interrelated components of athletic performance, ROM following each type of stretching was not separately assessed in the present study. Instead, the primary objective was to evaluate the overall functional effects of integrating different warm-up components rather than the isolated impact of each stretching modality. This approach allowed us to examine the acute, sport-specific response reflected in performance outcomes such as balance, agility, and reaction time. Previous research has already demonstrated that static, dynamic, and neural stretching can acutely increase joint ROM;[9,19,37] therefore, the present findings complement existing evidence by focusing on the combined influence of these stretching methods on functional and neuromuscular performance.

Confidential group allocation, assessor blinding, and group randomization increase the validity of the study. The limitations of our study can be listed as follows: We only observed the change from baseline in acute measurements after a session of acute bouts, so we only included a short-term follow-up, and it is unknown whether changes in flexibility are permanent. Additionally, long-term follow-up was not conducted to determine whether the observed changes in flexibility and athletic performance resulted in any changes in injury incidence within groups. Other limitations include the narrow age group. Future studies should include gender differences with larger sample sizes and examine longer-term effects of neural mobilization acute bouts.

The results show that neural mobilization is more effective than static and dynamic stretching in improving balance in the anterior direction. We think that it can be recommended as a part of the warm-up, especially for sports that require high balance activity. Neurodynamic techniques are often used to improve treatment outcomes in patient populations. In parallel with this study and the literature, it was concluded that neural mobilization can be used safely in the lower extremity to increase physical performance in soccer players. However, to be able to state these results clearly, future studies are needed to examine the long-term effect of neural mobilization used during the warm-up period on neural activity and injury risk.

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