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Original Article

Acute Effects of Nordic Hamstring Exercise on Hamstring Muscle Strength and Muscle Stiffness in Soccer Players

Efectos agudos del ejercicio nórdico de isquiotibiales sobre la fuerza muscular y la rigidez muscular de isquiotibiales en futbolistas

Hasan Aka[1], İlyas Karakaş[2]*, Erkan Özyılmaz[3] and Cengiz Akarçeşme[1]
[1] Gazi University. Sport Sciences Faculty. Ankara. Türkiye.
[2] National Defense University. Turkish Military Academy. Türkiye.
[3] Galatasaray Sports Club. Istanbul. Türkiye.

ABSTRACT
The aim of this study was to investigate the acute effect of Nordic Hamstring Exercise (NHE) applied to sub-elite soccer players on Hamstring (H) muscle strength values (maximum value and Total Work) and Muscle Stiffness (Semimembrenous and Biceps Femoris) values. 43 sub-elite male (16.50 ± 0.505) soccer players participated in the study voluntarily. Participants' H muscle strength values were determined with N3 brand device; Muscle Stiffness values were determined with myoton brand device. The normalcy analysis of the data acquired in the study was performed with the Shapiro-Wilk test. Participants' pre-test post-test comparisons were determined with the Wilcoxon Signed Ranks test. Based on the statistical analysis, it was identified that NHE utilized to sub-elite soccer players increased the Total Work (right-left leg) value of the H muscle strength values acutely, and the stiffness value of the Biceps Femoris muscle (right-left leg) significantly in the post-test. It can be concluded that acute application of NHE in soccer players increases H muscle streng and BF muscle stiffness, contributes to performance efficiency, and may serve as a preventive strategy against injuries.
Keywords: Strength; sports performance; resistance exercise.

RESUMEN
El objetivo de este estudio es investigar el efecto agudo del ejercicio nórdico para isquiotibiales (ENI) aplicado a jugadores de fútbol sub-élite sobre los valores de fuerza muscular de los isquiotibiales (H) (valor máximo y trabajo total) y los valores de rigidez muscular (semimembranoso y bíceps femoral). Participaron voluntariamente en el estudio 43 jugadores de fútbol sub-élite masculinos (16.50 ± 0.505). Los valores de fuerza muscular H de los participantes se determinaron con un aparato de la marca N3; los valores de rigidez muscular se determinaron con un aparato de la marca myoton. El análisis de normalidad de los datos obtenidos en el estudio se realizó con la prueba de Shapiro-Wilk. Las comparaciones preprueba-postprueba de los participantes se determinaron con la prueba de rangos con signo de Wilcoxon. Según los resultados del análisis estadístico, se determinó que la ENI aplicada a jugadores de fútbol sub-élite aumentó el valor de Trabajo Total (pierna derecha-izquierda) de los valores de fuerza del músculo H de forma aguda y el valor de rigidez del músculo Bíceps Femoral (pierna derecha-izquierda) de forma significativa en el post-test. Puede decirse que la ENI aplicada a los jugadores de fútbol aumenta de forma aguda la fuerza del músculo H y el valor de rigidez del músculo BF, proporciona eficiencia en el rendimiento y es una estrategia protectora contra las lesiones.
Palabras clave: Fuerza; rendimiento deportivo; ejercicio de resistencia.

INTRODUCTION
It is stated that hamstring (H) muscle strength is directly effective in the implementation of exercises such as knee joint stabilization, agility, acceleration, deceleration and change of direction in athletes (Greig and Naylor, 2017). H muscles maintain speed in movements such as flexion of the knee joint and expansion of the hip joint during sprinting, while also playing an active role in stabilizing the lower extremity (Perkins and Canavan, 2023). This muscle group (biceps femoris, semitendinosus and semimembranosus) is placed on the back of the thigh and has a direct effect on the performance of athletes who need to have high muscle strength, agility, speed and endurance levels (Latropoulos and Wheeler, 2024). Especially in team sports, H muscles produce force during knee flexion and hip extension in technical applications and improve the speed and accuracy of the movement (Edouard *et al*., 2022). However, high-intensity running, sudden changes of direction and jumping exercises in sports such as soccer increase the strength of the quadriceps muscle groups. This situation can cause strength imbalance by causing low H muscle power in athletes (Evangelidis *et al*., 2015). It is reported that insufficient H muscle group strength and strength imbalance between the hamstring and quadriceps muscles cause both performance losses and injuries in athletes (Morgan-Jones *et al*., 2000).

It is widely accepted that conditions such as low H muscle strength or insufficient activation increase the risk of anterior cruciate ligament injury and H muscle tear (Zebiş *et al*., 2013). It has been shown that the most important preventive exercises in minimizing these injuries in the H muscle are eccentric strength exercises and balance/proprioception

*Author for correspondence: İlyas Karakaş
e-mail: ilyas.karakas@msu.edu.tr
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exercises (McCall *et al*., 2015). For this reason, coaches and athletic performance experts turn to different exercises to increase H muscle strength. Nordic Hamstring Exercise (NHE) is an increasingly popular field exercise that develops eccentric H muscle strength without the need for any equipment (Mjølsnes *et al*., 2004; Cuthbert *et al*., 2020). Hamstring muscle activation in both joints during NHE requires more maximal eccentric muscle strength than traditional hamstring muscle exercises (Mjølsnes *et al*., 2004). Responses to eccentric muscle strength training for the hamstring muscle are multifactorial; they include changes in muscle structure such as increased motor unit discharge (Higbie *et al*., 1996) and hypertrophy (Bourne *et al*., 2017), lengthening of muscle fascicle length and decrease in pennation angle (Timmins *et al*., 2016). In addition, NHE applied to athletes has been reported to be an effective method for developing eccentric muscle strength, muscle activation and jump height in athletes (Delahunt *et al*., 2016).

In the literature, it is seen that NHE applied to athletes is generally aimed at its chronic effect on H muscle strength. In addition, investigating the effect of NHE applied on muscle stiffness, which may be an injury factor in athletes, may be important for sports health and performance specialists. Therefore, it is thought that there is a deficiency in the literature regarding the acute effect of NHE applied to soccer players on H muscle strength (Maximum value, Total Work) and Muscle Stiffness. Based on this, the purpose of this study was to examine the acute effect of NHE applied to soccer players on H muscle strength values and muscle stiffness values of semimembranosus (SM) and Biceps Femoris (BF) muscles.

MATERIAL AND METHODS

This research was implemented according to the final edition of the Declaration of Helsinki. Ethical confirmation for the research was gained from the Ethics Committee of the Faculty of Sport Sciences at Gazi University (Date: 18.02.2025; Approval Number: E-77082166-604.01-1189324).

Research Group

43 sub-elite male (16.50 ± 0.505) soccer players participated in the study voluntarily. Participants were asked to have played licensed soccer for at least three years and not to have a history of lower extremity injury in the last six months.

Tests and Data Collection Procedures

After the warm-up exercises applied to the players on their days off, H muscle strength assessments and pre-test measurements of muscle stiffness values were performed. Post-test measurements were performed one day after the pre-test measurements. Before the measurements, a detailed presentation about the study was made to the participants. Informative volunteer forms were signed by the participants. The pre-test and post-test measurements of the participants were administered on different days, coinciding with their days off. A standard warm-up program was applied before starting the measurements. Muscle stiffness and H muscle strength measurements were repeated 3 times and the highest value was recorded.

Eccentric H Muscle Strength Measurement

In this test, the N3 Nordic Hamstring Curl Exercise Device (N3 Easytech, San Lorenzo, Firenze, Italy) was used to assess the athletes eccentric hamstring muscle strength. The intraclass correlation coefficients (ICC) for this device are reported to be high, ranging from 0.89 to 0.95, indicating excellent reliability for eccentric hamstring strength measurements (Sannicandro *et al*., 2022). The soccers placed their knees on the soft pad of the device. The ankles were locked so that the locks of the device were just above the lateral malleoli. Measurements were reiterated three times at 90-second breaks and the arithmetic mean value of all measurements was calculated.

Muscle Stiffness Measurement

The stiffness values of the participants' SM and BF muscles were determined with a Myotonpro (Myoton AS, Estonia) brand device. Myotonpro measures the tissue characteristics of ordinarily damped vibrations developed by a short (15 ms) mechanical touch to the skin surface. The Myotonpro device was implemented to the hamstring tissue in the flat position for muscle tone and viscosity properties. The procedure was carried out at ambient temperature. The participants were instructed to refrain from physical activity on the day of the procedure. They were positioned in a prone position and at rest on a horizontal testing surface. The participants were instructed to keep their legs fully relaxed during the assessment to prevent any influence on tissue stiffness. The midpoint of the muscle bulge and the tendon center was identified as 12.8 cm below the sacroiliac joint along the line connecting the sacroiliac joint and the lateral epicondyle. All readings were taken by positioning the device perpendicular to the skin in the specified area to minimize the gravitational effect on tissue characteristics. The measurements were repeated three times with 15-second intervals, and the mean value of all measurements was calculated (Van der Made *et al*., 2015).

Data Analysis

The IBM SPSS 22.0 package program was used in the analysis of the data. Mean and standard deviation values were calculated using the descriptive statistics method for the participants' variables. After the descriptive statistics were performed, the Shapiro-Wilk test was applied to determine the normality distribution of the data. Since the data did not show a normal distribution, the Wilcoxon Signed Rank test, a non-parametric test, was used to compare the values within the groups. The significance level was determined as $p<0.05$.

RESULTS

Table 1. Anthropometric characteristics of the participants.
Tabla 1. Características antropométricas de los participantes.

Variables	n	Mean ± Sd
Age (year)	46	16.50 ± 0.50
Height (cm)	46	177.10 ± 6.07
Body weight (kg)	46	68.84 ± 7.92

Table 2. Differences between the H muscle strength and muscle stiffness values of the participants before and after NHE.
Tabla 2. Diferencias entre los valores de fuerza muscular H y rigidez muscular de los participantes antes y después de la ENI.

Variable		Mean ± Sd	Z	p	Es
H_max_value_right	Pre-test	252.1 ± 47.45	-1.37	0.169	0.01
	Post-test	257.1 ± 48.32			
H_max_value_left	Pre-test	247.4 ± 47.00	-1.22	0.220	0.01
	Post-test	252.2 ± 40.98			
H_TW_ left	Pre-test	3322.2 ±1284.9	-5.48	**0.000**	0.16
	Post-test	4738.7 ± 2146.7			
H_TW_right	Pre-test	3302.5 ± 1335.9	-5.11	**0.000**	0.74
	Post-test	4610.7 ± 2106.8			
Stiffness_ left _S.M	Pre-test	287.3 ± 45.70	-1.84	0.065	0.02
	Post-test	297.6 ± 46.58			
Stiffness_ left _B.F	Pre-test	298.0 ± 52.15	-3.47	**0.001**	0.04
	Post-test	317.7 ± 56.34			
Stiffness_right _S.M	Pre-test	302.8 ± 48.60	-1.25	0.211	0.01
	Post-test	308.5 ± 52.78			
Stiffness_right _B.F	Pre-test	305.4 ± 48.88	-3.79	**0.000**	0.03
	Post-test	323.5 ± 61.41			

H: Hamstring, max_value: Maximum value, TW: Total Work, SM: Semimembronous, BF: Biceps Femoris.

When Table 2 is examined, a significant difference was determined between the pre-test and post-test values of the Hamstring muscle group Total Work (left and right); B.F. (left and right) muscle stiffness values in favor of the post-test ($p < 0.05$).

DISCUSSION

It is reported that the H muscle group, which is vital for athlete health and performance, increases the risk of injuries such as anterior cruciate ligament injuries and H muscle tears due to low strength or insufficient activation (Zebiş *et al*., 2013). It is known that coaches focus on some preventive exercises such as eccentric strength exercises, in order to minimize the risk of injury that may occur in the H muscle group. Nordic Hamstring Exercise (NHE) is an exercise that develops eccentric H muscle strength using body weight (Mjølsnes *et al*., 2004; Cuthbert *et al*., 2020). Studies have also shown that NHE increases the strength of the H muscle group and is an effective application in reducing injury rates (Seymore *et al*., 2017). It requires more maximal eccentric muscle strength during NHE application (Mjølsnes *et al*., 2004). The responses of the applied NHE training are multifactorial; it has been clearly demonstrated in the literature that it includes changes in muscle structure such as increased motor unit discharge (Higbie *et al*., 1996) and hypertrophy (Bourne *et al*., 2017), lengthening of muscle fascicle length and decrease in pennation angle (Timmins *et al*., 2016).

In this study, according to the statistical analysis results of NHE muscle stiffness (MS) values applied to football players, it was determined that there was a significant difference between the pre-test and post-test values of the stiffness values of the BF muscles (right and left) in favor of the post-test. It was understood that NHE applied to soccer players acutely increased the MS value in the BF muscle. In the H muscle group, Semimembronosus (SM) is located in the medial part of the posterior thigh, and Biceps Femoris (BF) is located in the lateral part of the thigh (Balius *et al*., 2019). Therefore, when eccentric NHE is applied, the fact that the load or stimulus on the short and long heads of the BF muscle is higher may be a reason for the significant increase in the stiffness value of the BF muscle in both legs in our study result. MS is a biomechanical property of the muscle and is an important function of muscle strength in healthy individuals (Hug *et al*., 2015; Klauser *et al*., 2014). MS has been shown to affect performance in athletic tasks performed by the lower extremity, such as jumping, running, and changing direction (Brazier *et al*., 2019). A study by Kalkhoven *et al*. (2018) found that higher mechanical stiffness was beneficial for athletic performance in sub-elite soccer players. However, there is a consensus that an excessive increase or decrease in MS level can negatively affect sports performance and cause sports injuries (Koulouris *et al*., 2003; Kurtdere *et al*., 2021). Therefore, MS should be kept within its normal stiffness range. Injury, spasm, cramp, and overtraining increase MS levels, but stretching and other myofascial release techniques can reduce MS levels (Akkoc *et al*., 2018; Morales *et al*., 2017). Therefore, the NHE applied to soccer players in our study can be considered as a factor that increases the MS values of the BF muscles acutely in the right and left legs, increasing performance efficiency.

In this study, according to the statistical analysis results of the participants' H muscle group strength values, a significant difference was determined between the pre-test and post-test values of the TW (left and right) values in favor of the post-test. It is noteworthy that the NHE applied to soccer players caused an acute significant increase in the TW values of the H muscle group. This can be considered as a situation that coaches and performance experts should take into consideration during training. When NHE is applied, the significantly increased TW value of the H muscle group and the increased max values, even if there is no significant increase, can be an important variable in athlete performance. In a study conducted by Bourne *et al*. (2017) they showed that eccentric NHE increased hamstring muscle volume even in the short term from a physiological perspective. Therefore, the acutely increased TW value of the H muscle group in soccer players in our study supports the conclusion in the literature that NHE improves H muscle strength chronically.

The absence of a study in the literature examining the acute effect of NHE applied to participants on H muscle strength values can be considered as a limiting factor in comparing our results.

When looking at some studies on the chronic effect of NHE, Seymore *et al*. (2017) stated that NHE, which provides strength increase with eccentric contraction, is important in reducing hamstring injury rates; Petersen *et al*. (2011) stated that NHE applied in addition to training can reduce acute H wounds in each professional and amateur soccer players; Evangelidis *et al*. (2015) stated that it is an effective method in reducing strength imbalances in sports branches such as soccer and basketball.

CONCLUSIONS

NHE applied to sub-elite soccer players significantly increased the TW (right-left leg) value of H muscle strength values acutely and the stiffness (right-left leg) value of the BF muscle in the post-test. It can be said that NHE applied to soccer players is a protective strategy against injuries by increasing the H muscle strength and Muscle Stiffness values acutely.

From a practical standpoint, incorporating NHE into regular training sessions could be beneficial for coaches, and strength and conditioning professionals, seeking to improve performance efficiency and reduce the risk of hamstring-related injuries. It is recommended that NHE be integrated systematically into warm-up or strength training routines, considering training load, athlete experience level, and recovery strategies. Future studies could explore its effects across different age groups, competitive levels, and in combination with other preventive training methods to optimize its application in sports practice.

CONFLICTS OF INTEREST

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

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