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Original Article

The Correlation Between Nordic Hamstring Strength and Agility and Speed Performance in National Badminton Athletes

La correlación entre la fuerza de los isquiotibiales nórdicos y el rendimiento en agilidad y velocidad en atletas nacionales de bádminton

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ABSTRACT

The purpose of this research was to determine the connection between Nordic hamstring power, and agility and speed performance among Turkish national badminton players. The study included 11 male and 6 female national badminton players. The hamstring muscle power of the athletes was measured using the H-Bord machine. Additionally, agility performance was evaluated using the Agility T-Test, and the 10-meter sprint performance was measured using an electronic photocell. An analysis of the study findings revealed a statistically significant difference between NHTecc(a) and NHTecc(b) hamstring muscle strength, and the T-test and 10-meter sprint scores in terms of the gender variable. Furthermore, a strong negative correlation was observed between participants' NHTecc(a) and NHTecc(b) leg strength and their T-test performance. Supporting this finding, a negative correlation was also identified between NHTecc(a) and NHTecc(b) leg power and 10-meter sprint performance. In conclusion, this research analyzed the effects of Nordic hamstring strength on agility and speed performance in badminton athletes and identified a strong negative correlation between these variables. In this context, it is suggested that training programs aimed at improving eccentric muscle strength may help optimize agility and speed performance, particularly in the sport of badminton.

Keywords: Eccentric Strength; Performance Metrics; Training Optimization.

RESUMEN

El propósito de esta investigación es determinar la conexión entre la potencia de los isquiotibiales nórdicos y el rendimiento en agilidad y velocidad entre los jugadores nacionales turcos de bádminton. En el estudio participaron 11 jugadores masculinos y 6 jugadoras femeninos nacionales de bádminton. La fuerza de los músculos isquiotibiales de los atletas se midió utilizando la máquina H-Bord. Además, el rendimiento en agilidad se evaluó utilizando la prueba T de agilidad, y el rendimiento en sprint de 10 m se midió utilizando una fotocélula electrónica. Un análisis de los resultados del estudio reveló una diferencia estadísticamente significativa entre la fuerza muscular isquiotibial NİPecc(a) y NİPecc(b) y las puntuaciones de la prueba T y del sprint de 10 m en cuanto a la variable de género. En conclusión, esta investigación analizó los efectos de la fuerza de los isquiotibiales nórdicos en el rendimiento de agilidad y velocidad en atletas de bádminton e identificó una fuerte correlación negativa entre estas variables. En este contexto, se sugiere que los programas de entrenamiento dirigidos a mejorar la fuerza muscular excéntrica pueden ayudar a optimizar el rendimiento en agilidad y velocidad, particularmente en el deporte del bádminton.

Palabras clave: Fuerza Excéntrica; Métricas de Rendimiento; Optimización del Entrenamiento.

INTRODUCTION

The skill to sprint and switch direction is a fundamental element of physical performance in racket sports (Hader *et al*., 2015). Badminton is a high-intensity, intermittent racket sport that demands a high degree of technical skill, strategic consciousness, and physical capacity during both training and competitiveness (Faude *et al*., 2007).

On-court badminton movements comprise starts and stops, sprints, jumps, lunges, and rapid changes of direction. Badminton players must execute explosive movements with frequent directional changes to capture the shuttlecock before it touches the ground, which places a high eccentric burden primarily on the muscles of the lower extremities (Abián *et al*., 2016).

During sprinting, the hamstring muscles eccentrically decelerate knee expansion during the shaking stage, and subsequently create horizontal forces by producing hip expansion and knee flexion moments during the stance phase (Morin *et al*., 2015; Higashihara *et al*., 2018). Accordingly, previous studies have described a relationship between sprint performance and eccentric hamstring power, activation of the biceps femoris long head, and explosive knee flexion torque. These results highlight the vital role of the hamstring muscles in sprint performance (Krommes *et al*., 2017; Ishøi *et al*., 2018).

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Badminton players must repeatedly perform movements within the court at high speed and intensity within a short time frame (Cabello Manrique and González-Badillo, 2003). Directional changes involving slowdown pursued by the reacceleration of the whole body or specific body sections occur almost continuously. Consequently, players need to change their direction towards the center of the playground, and subsequently adjust to the opponent's returns (Paterson *et al*., 2016). Therefore, agility can be considered one of the essential motor (athletic) skills required to excel as an elite-level badminton player.

Eccentric training induces bigger adaptive responses in both muscle strength and architecture compared to concentric training. The differences in adaptation between contraction types result from the distinct mechanisms used to generate force: eccentric movements involve the active lengthening of muscle fascicles, whereas concentric movements involve their active shortening. The slow eccentric nature of the Nordic Hamstring Exercise (NHE), provides a stimulus in which myosin heads are already bound to actin and are compelled to separate due to the prolongation of cross-bridges, leading to muscle detriment (Franchi *et al*., 2017).

NHE is one of the most commonly used eccentric exercises across various sports disciplines (Ishøi *et al*., 2018). Such exercises forestall sports injuries, accelerate salvation after bruises, and enhance athletic performance during physical activities (Bourne *et al*., 2015; van Dyk *et al*., 2017).

In conclusion, sprint and agility assessments are among the key conditional features for monitoring the physical performance of badminton players (Bhosale *et al*., 2020). Considering the connection between hamstring muscle strength, and dash and agility performance, badminton players can gain a competitive advantage by improving their agility and speed. Therefore, the aim of this study was to determine the connection between Nordic hamstring strength and agility and revolutions per minute performance in national badminton athletes.

MATERIALS AND METHODS

This research was implemented according to the final edition of the Declaration of Helsinki, and with permission granted by the Turkish Badminton Federation under the Ministry of Youth and Sports of the Republic of Türkiye. Ethical confirmation for the research was gained from the Ethics Committee of the Faculty of Sport Sciences at Atatürk University (Date: 24.12.2024; Approval Number: E-70400699-000-2400423906).

Research Group

The study included 11 male and 6 female badminton athletes with an average age of 17.47±1.62 years, an average body weight of 62.47±6.14 kg, a mean height of 172±7.46 cm, and a BMI of 21.09±1.57. These athletes were members of the youth national badminton teams competing in the 2024-2025 season. All participants trained regularly for at least five days a week, and had been actively playing badminton for a minimum of 5 years.

The selection of participants was based on voluntary participation among national team athletes, which inherently imposed a natural limitation on the sample size. Additionally, despite the differences in gender distribution, statistical analyses, were conducted to ensure the validity and representativeness of the findings.

Tests and Data Collection Procedures

Participants were instructed to refrain from performing intense exercise and consume performance-enhancing ergogenic supplements at least 48 hours before the measurements. Physical assessments were conducted between 09:00 and 11:00 in the morning. The test sessions were carried out over two consecutive days.

- Day 1: Anthropometric measurements and eccentric hamstring strength assessments were performed using the Nordic Hamstring device.
- Day 2: Agility tests using the BlazePod device (T-test) and 10-meter sprint tests using an electronic photocell system were conducted.

Before beginning the tests, participants completed a standardized warm-up program lasting approximately 15 minutes, which consisted of two phases:

1. General warm-up: This phase aimed to increase body temperature through low-intensity running, followed by general stretching exercises.
2. Specific warm-up: In this phase, the exercises to be performed during the tests were repeated at moderate intensity.

Anthropometric Measurements

The body weight of the participants were measured using a Tanita BC 730 digital scale (Tanita Health Equipment, Kowloon, Hong Kong). Height measurements were obtained in centimeters using a Harpenden stadiometer (Holtain Limited, Crosswell, Crymych, Pembs, United Kingdom). During measurements, participants were instructed to stand barefoot, with their heels together, and maintain an upright posture. Measurements were taken with the participants' eyes facing forward, holding their breath after a deep inspiration, and the highest point of the head was measured with an accuracy of 1 mm.

Body weight measurements were performed while participants wore only shorts and sports T-shirts. After stepping onto the device, the relevant data were displayed on the screen and recorded. The Body Mass Index (BMI) was then calculated using the formula: BMI = body mass (in kilograms) / height^2 (in meters) (Garrow and Webster, 1985).

10-Meter Sprint Test

For the 10-meter sprint test, a straight 10-meter distance was marked on a badminton court. An electronic photocell timing system with two gates and a precision of ±0.01 seconds (Seven Elektronik, İstanbul, Türkiye), was placed at the start and finish points to record the measurements.

H-Bord Nordic Hamstring Eccentric Test (NHET)

The H-Bord is a new portable device designed for the Nordic hamstring test. The NHT was conducted using the H-Bord (iVMES, Ankara, Türkiye). The dimensions of this device are 1103 mm in length, 550 mm in breadth, and 320 mm in height, with a weight of 25 kg. Its sampling rate is 50 Hz (standard), which can be increased up to 400 Hz. Each sensor has a load capacity of 1000 N (100 kg) per sensor, with a measurement resolution of 1 N (100 g). Additionally, the device supports Bluetooth 5.0 Low Energy (BLE) wireless connections, allowing instant data acquisition and report generation through the iVMES mobile application.

Figure 1. H-Bord device (iVMES, 2024).
Figura 1. Dispositivo H-Bord (iVMES, 2024).

Before the measurements, each participant performed at least one familiarization trial. The Nordic Hamstring Test (NHT) was conducted in eccentric mode (NHTecc). The NHTecc involved three maximum eccentric contractions with a 10-second rest gap between repetitions. During the tests, participants were instructed to slowly lean forward while maintaining eccentric hamstring contraction until they could no longer sustain it, allowing themselves to fall to the ground with their palms. The movement technique required participants to minimize hip flexion and lumbar lordosis as much as possible, while maintaining a straight line from the shoulders to the knees throughout the repetitions. Any repetition in which participants exhibited casualty of control during landing or excessive waist action was excluded from the measurements (Akarçeşme *et al*., 2024).

T-Test

T-Test is a popular method for evaluating agility performance (Pauole *et al*., 2000). BlazePod was used for this test (BlazePod, Miami, Florida, United States). BlazePod is a modular training tool designed to help participants improve agility, balance, power, endurance, reaction time, and speed. This innovative system offers over 100 interactive exercises that can be performed anytime and anywhere, by utilizing

Figure 2. Nordic hamstring eccentric strength test performed with the H-Bord device.
Figura 2. Prueba de fuerza excéntrica nórdica de isquiotibiales realizada con el dispositivo H-Bord.

sensors and visual cues through light pulses. Additionally, it provides performance statistics in milliseconds (Mohamed Prince, 2019). The extinguishing of the light indicates successful contact. Before starting the test, the athlete waits in a standing start position behind point A, as shown in Figure 3. Upon receiving the command from the application, the athlete starts and sprints 10 meters to point B, where they touch the illuminated button, causing the light to turn off. After the light extinguishes, the athlete moves laterally 5 meters to the right to point C, where they touch another illuminated button, extinguishing the light. They then move laterally 5 meters to the left to point D, where they touch the illuminated button to turn off the light. Finally, the athlete runs backward for 10 meters to return to the starting point A and touches the button, extinguishing the light and completing the check. If the athlete fails to touch the button or extinguish the illuminated light at any point, the test is terminated (this rule applies to all contact points). The BlazePod system synchronizes with an application-based platform that provides real-time feedback for each participant after every test, including the number of touches, reaction times, and errors. Participants were given 15 seconds of rest between repetitions of the same test, and a one-minute rest before starting the next test in the sequence.

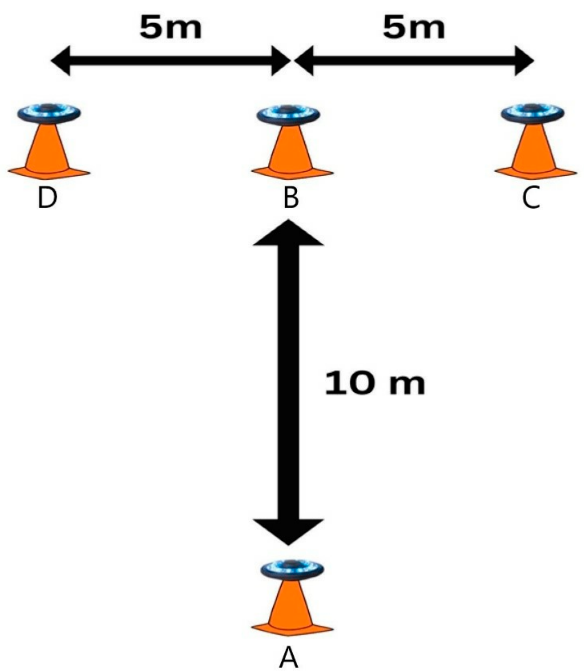

Figure 3. Agility T-test illustration (Steff *et al*., 2024).
Figura 3. Imagen de la prueba T de agilidad (Steff *et al*., 2024).

Data Analysis
The data obtained in the study were analyzed using IBM SPSS Statistics 26.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro-Wilk test. The results indicated that the Nordic Hamstring Test eccentric strength values (NHTecc(a), NHTecc(b)), T-test times, and 10-meter sprint times did not meet the assumption of normality ($p < 0.05$). Therefore, non-parametric tests were applied. Since the data did not follow a normal distribution, the Nordic hamstring eccentric strength values, T-test, and 10-meter sprint test results were compared across gender using the Mann-Whitney U test. Additionally, the relationship between eccentric hamstring muscle strength and the T-test and 10-meter sprint test performances, was examined using Spearman's correlation analysis. A significance level of $p < 0.05$ was considered for all analyses.

RESULTS
The male badminton athletes who participated in the study had a mean age of 17.81±1.47 years, a mean height of 177±3.09 cm, an average body weight of 65.18±5.21 kg, and a Body Mass Index (BMI) of 20.79±1.41. The female badminton athletes had a mean age of 16.83±1.83 years, a mean height of 163±2.60 cm, an average body weight of 57.50±4.54 kg, and a BMI of 21.65±1.82.

When examining Table 1, statistically significant differences were observed by gender in NHTecc(a) ($z = -2.714$; $p < 0.05$) and NHTecc(b) ($z = -2.312$; $p < 0.05$) hamstring strength, as well as in T-test ($z = -3.317$; $p < 0.05$) and 10-meter sprint scores ($z = -3.321$; $p < 0.05$).

When examining Table 2, a strong negative correlation is observed between NHTecc(a) leg strength and T-test performance ($r_s(15) = -.806$, $p = 0.001$). Similarly, a strong negative correlation is evident between NHTecc(b) leg strength and T-test performance ($r_s(15) = -.667$, $p = 0.003$). Furthermore, the same table indicates a strong negative correlation between NHTecc(a) leg strength and 10-meter sprint performance ($r_s(15) = -.778$, $p = 0.001$). Likewise, a strong negative correlation is observed between NHTecc(b) leg strength and 10-meter sprint performance ($r_s(15) = -.745$, $p = 0.001$).

Table 1. Comparative analysis of Nordic hamstring eccentric strength test results and athletic performance metrics by gender using the Mann-Whitney U test.
Tabla 1. Análisis comparativo de los resultados del Test de Fuerza Excéntrica de los Isquiotibiales Nórdicos y las Métricas de Rendimiento Atlético según el género, utilizando la prueba de Mann-Whitney U.

Parameters	Gender	n	Mean±SD	z	p
$NHT_{ecc}^{(a)}$ (N)	Male Female	11 6	295.26±11.45 225.55±4.50	-2.714	0.00*
$NHT_{ecc}^{(b)}$ (N)	Male Female	11 6	263.06±11.09 156,82±5.17	-2.312	0.02*
T-Test (sec)	Male Female	11 6	11.35±0.72 13.58±1.12	-3.317	0.00*
10-Meter Sprint Test (sec)	Male Female	11 6	1.65±0.07 1.88±0.02	-3.321	0.00*

$p < 0.05$ indicates a significant difference (2-tailed).
NHTecc: Nordic Hamstring Test in eccentric mode; (a): Dominant leg; (b): Non-dominant leg.

Table 2. Spearman correlation analysis of the relationship between eccentric hamstring strength and T-test and 10-meter sprint test.
Tabla 2. Análisis de correlación de Spearman sobre la relación entre la fuerza excéntrica de los isquiotibiales y el Test T y la prueba de velocidad de 10 metros.

Tests		$NHT_{ecc}^{(a)}$ (N)	$NHT_{ecc}^{(b)}$ (N)
T-Test (sec)	r	-.806**	-.667**
	p	.001	.003
	n	17	17
10-Meter Sprint Test (sec)	r	-.778**	-.745**
	p	.001	.001
	n	17	17

$p < 0.05$ indicates a significant difference (2-tailed).
NHTecc: Nordic Hamstring Test in eccentric mode; (a): Dominant leg; (b): Non-dominant leg.

DISCUSSION
The connection between hamstring power and athletic performance has been the subject of numerous studies (Ishøi *et al*., 2019; Demirhan *et al*., 2021; Jiang *et al*., 2023; Altundağ *et al*., 2024). In this study, a strong negative correlation was identified between Nordic hamstring leg strength, and agility and speed performance (Table 2). Accordingly, it was observed that as leg strength increased, agility and speed performance times improved.

The hamstrings are a biarticular muscular group that simultaneously acts on two knuckles, contributing to genuflection and thigh extension. Furthermore, the hamstrings play a critical role in the improvement of horizontal force components while sprinting under non-fatiguing circumstances (Edouard *et al*., 2018). In a study by Bautista *et al*. (2021) investigating the impacts of Nordic hamstring exercise on sprint performance and eccentric genuflector power, a 0.04-second reduction in sprint times was observed alongside an increase in Nordic hamstring strength. Similarly, research by Marković *et al*. (2020) on young indoor football athletes demonstrated that improved Nordic hamstring strength led to enhanced sprint times. These findings align with the results of our study. However, the literature also includes studies reporting different outcomes. For instance, Suarez-Arrones *et al*. (2019) searched the relationship between Nordic hamstring strength and sprint performance in professional male soccer athletes, and found no clear association. Likewise, a study by Whyte *et al*. (2024) on female Gaelic football players (a traditional Irish sport) reported no remarkable relationship between genu flexor strength and sprint performance.

Badminton is one of the fastest competitive racket sports in the world (Phomsoupha and Laffaye, 2015). During a race, players perform 6 to 12 beats within a rally period arraying from 6 to 10 seconds. Because of the high velocity of the shuttlecock and the frequent strokes, badminton players require abilities such as running, accelerating, decelerating, jumping, lunging, and switching course (Laffaye *et al*., 2015; Lee and Loh, 2019). Consequently, athletes are expected to execute rapid directional changes, successive climbs, attacks, and various speeds and slowdowns (Cabello Manrique and Gonzalez-Badillo, 2003). Lower extremity reactive power and postural control are critical factors that contribute to athletes' ability to change direction quickly and effectively prevent injuries (Borghuis *et al*., 2008). Research has shown significant relationships between eccentric hamstring strength and agility performance (Brughelli *et al*., 2008; Fernandez-Fernandez *et al*., 2022; Horníková and Zemková, 2021). The results of these studies are inconsistent with the conclusion of our research.

When the literature is broadly reviewed, significant relationships are observed between Nordic hamstring strength and agility performance. Agility is a critical determinant of performance across various sports disciplines (Brughelli *et al*., 2008; Sheppard and Young, 2006; Fernandez-Fernandez *et al*., 2022; Horníková and Zemková, 2021). The relationship between strength, agility, and speed performance may vary depending on athletes' specific sports, training status, gender, and injury history. In badminton, considering that players are frequently forced to change direction within a confined space due to the shuttlecock's movement and the opponent's actions, agility performance can be regarded as essential. It is known that swing-of-direction speed is influenced by elements such as linear running velocity, and shank muscular characteristics (strength, power, and reactive force) (Young *et al*., 2002). The Nordic Hamstring Exercise (NHE) increases eccentric hamstring power (Delahunt *et al*., 2016). Regardless of the evaluation type used, NHE programs consistently demonstrate significant improvements in eccentric strength across studies. When tests are performed using an isokinetic dynamometer, strength gains range from 10% to 15%, whereas studies utilizing the NHE device report increases of 16% to 26% (Medeiros *et al*., 2021). In this context, the portable device used in this research offers a practical application for daily assessment and improvement of eccentric flexor muscle strength.

Previous studies have extensively examined the relationship between eccentric hamstring strength and performance metrics such as sprint speed and agility in sports like football, rugby, and basketball. However, the findings of this study suggest that the unique biomechanical demands and movement patterns of badminton may play a decisive role in this relationship. Unlike field-based sports, badminton requires athletes to execute frequent multidirectional changes, rapid accelerations and decelerations within a confined space, imposing significant eccentric loading on the lower extremities. This distinct movement pattern may alter the functional contribution of eccentric hamstring strength, potentially explaining the observed differences in correlation results. Additionally, variations in sample characteristics, testing protocols, and measurement tools across studies may further contribute to these discrepancies. Future research should provide a more detailed investigation into sport-specific eccentric hamstring adaptations and their effects on agility and sprint performance, allowing for a more comprehensive understanding of these differences.

CONCLUSIONS

In conclusion, by examining the effects of Nordic hamstring strength on agility and speed performance in badminton athletes and identifying a strong negative correlation between these variables, suggests that an increase in eccentric hamstring strength may contribute to improvements in agility and sprint performance. From a practical perspective, these findings indicate that conditioning programs for badminton players should consider the balance between eccentric strength training and agility/speed development. Coaches and practitioners can incorporate eccentric hamstring exercises into training regimens to enhance agility and sprint performance.

Future studies should further investigate the effects of Nordic hamstring exercises across different sport disciplines to identify potential variations in training protocols. Additionally, longitudinal studies examining the long-term effects of eccentric hamstring strength training on agility and sprint performance, could provide insights into how muscle adaptations influence movement efficiency over time. Expanding the sample size and conducting research on athletes at different performance levels may also enhance the generalizability of these findings.

CONFLICTS OF INTEREST

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

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