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Investigation of the Relationship Between Hip Muscle Strength and Athletic Performance: A Study on Elite Athletes

Kalça Kas Gücü ve Atletik Performans Arasındaki İlişkinin İncelenmesi: Elit Sporcular Üzerine Bir Çalışma

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ABSTRACT

Background: Athlete performance refers to an individual's ability to execute physical tasks efficiently and effectively within their sport, encompassing strength, power, endurance, agility, flexibility, and coordination. Key determinants such as muscular strength and motor skill proficiency collectively influence athletic outcomes. Muscles responsible for hip flexion, extension, rotation, abduction, and adduction serve distinct functions. However, limited research has identified which specific muscles most significantly influence jump height (JH), peak power (PP), reactive pro agility (RPA), and the relative strength index (RSI).

Materials and Methods: A total of 34 athletes were included in the study, with performance measurements obtained using the Vald performance analysis systems.

Results: Correlation analysis indicated that JH, PP, RSI, and RPA were significantly associated with hip extension right strength (HER). In addition, JH was significantly associated with left hip flexor (HFL) strength. However, linear regression analysis revealed that HER and HFL strengths significantly influenced JH, whereas HER strength influenced RSI. HER also had a notable impact on RPA and PP.

Conclusion: These findings provide valuable insights into the role of HER in key athletic performance metrics. By identifying key muscle groups influencing JH, reactive strength, and agility, this study supports the development of targeted strength training programs for professional athletes.

Keywords: Elite athlete, hip muscles, JH, PP, RPA, RSI

ÖZ

Amaç: Atlet performansı, bireyin spor dalında fiziksel görevleri verimli ve etkili bir şekilde yerine getirme yeteneğini ifade eder ve güç, kuvvet, dayanıklılık, çeviklik, esneklik ve koordinasyonu kapsar. Kas gücü ve motor beceri yeterliliği gibi temel belirleyiciler, atletik sonuçları topluca etkiler. Kalça fleksiyonu, ekstansiyonu, rotasyonu, abdüksiyonu ve adduksiyonu kasları farklı işlevlere sahiptir. Bununla birlikte, sıçrama yüksekliğini (JH), tepe gücünü (PP), reaktif pro çevikliği (RPA) ve göreceli kuvvet indeksini (RSI) en önemli ölçüde etkileyen spesifik kasları belirleyen sınırlı araştırma bulunmaktadır.

Gereç ve Yöntemler: Çalışmaya toplam 34 atlet dahil edildi ve performans ölçümleri Vald performans analiz sistemleri kullanılarak elde edildi.

Bulgular: Korelasyon analizi, JH, PP, RSI ve RPA'nın sağ kalça ekstansiyonu (HER) kuvvetiyle anlamlı derecede ilişkili olduğunu gösterdi. Ek olarak, JH sol kalça fleksör (HFL) kuvvetiyle anlamlı derecede ilişkiliydi. Ancak doğrusal regresyon analizi HER ve HFL kuvvetlerinin JH'yi önemli ölçüde etkilediğini, HER kuvvetinin ise RSI'yı etkilediğini ortaya koymuştur. HER ayrıca RPA ve PP üzerinde de kayda değer bir etkiye sahipti.

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ÖZ

Sonuç: Bu bulgular, HER'in temel atletik performans ölçütlerindeki rolüne dair değerli bilgiler sağlamaktadır. Sıçrama yüksekliği, reaktif kuvvet ve çevikliği etkileyen temel kas gruplarını belirleyerek, bu çalışma profesyonel sporcular için hedefli kuvvet antrenmanı programlarının geliştirilmesini desteklemektedir.

Anahtar Kelimeler: Elit sporcu, kalça kasları, JH, PP, RPA, RSI

Introduction

Athlete performance refers to the ability of an individual to execute physical tasks efficiently and effectively within their sport, encompassing strength, power, endurance, agility, flexibility, and coordination. It is determined by a complex interplay of physiological, biomechanical, psychological, and environmental factors (1). Key determinants such as muscular strength, aerobic and anaerobic capacity, neuromuscular control, and motor skill proficiency collectively influence athletic outcomes (2). Advances in sports science have emphasized the importance of individualized performance analysis to identify strengths and limitations unique to each athlete (3). Objective assessments—such as jump height (JH), peak power, and reactive strength index—provide quantitative insights into muscular function and training effectiveness (2). Additionally, performance optimization requires integrating targeted strength conditioning, nutrition, recovery strategies, and psychological resilience training (4). Understanding the multifactorial nature of athlete performance enables the development of evidence-based interventions aimed at maximizing competitive success and minimizing injury risk (5).

The muscles governing hip movements encompass a range of functions: flexors, extensors, rotators, abductors, and adductors (6). Strong and functional hip muscles are indispensable for maintaining proper pelvic alignment, supporting the spine's natural curvature, and sustaining correct posture (7). These muscles also serve a crucial role in balance, particularly when standing on one leg, and act as propellers during running (8). The bones, joints, and muscles surrounding the pelvis and hip are pivotal for movement quality and the prevention of musculoskeletal ailments (9). Ensuring the strength and equilibrium among these structures is imperative. Furthermore, in addition to buttressing the spine during weightlifting maneuvers, hip muscles safeguard against knee injuries that can arise during weightlifting and running activities (10).

Jumping, defined as the action where an athlete propels themselves off the support surface, lifting off either vertically or horizontally and suspending themselves in the air momentarily, constitutes a fundamental aspect of athletic performance (11). Successful jumping relies on a culmination of intricate movements executed in a coordinated manner (12). Various factors influence the efficacy of jumping: attainment of maximal strength and explosive power within the muscle groups predominantly involved in jumping, particularly those of the lower extremities (1,13), alongside achieving a balance in agonist-antagonist muscle activity (14) and symmetrical force distribution between the two lower limbs (15), as well as considerations of the bone, joint, and ligament integrity of the hip, knee, and ankle regions, and the maintenance of effective lumbar stabilization (16). Additionally, proper jumping techniques and an individual's capacity to execute them play pivotal roles. Notably, the efficacy of jumping can be further influenced by one's ability to employ correct breathing techniques (17). Moreover, the maximum height attained in a jump, serving as a measure of muscular strength of the lower extremities, is valuable for assessing an individual's functional capacity and performance across a range of sports disciplines. Indeed, the vertical jump stands as a fundamental motor skill in various team sports such as football, basketball, volleyball, and handball (16).

In athletic endeavors, leveraging jumping force during performance facilitates the proficient execution of challenging movements, ensuring effectiveness and attainment of desired levels through the extension of airborne duration (18). Strength, defined the capacity to apply force, is a cornerstone of sport and underpins performance in recreational activities. It holds the premier position among fitness skills, owing to the athlete's inherent requirement for a certain degree of strength in every movement undertaken (19). Through the utilization of jumping force in performance, athletes optimize the execution of demanding maneuvers, enabling effectiveness and precision while prolonging flight time (18). Several techniques exist for evaluating lower extremity muscle strength, with isokinetic assessments being the most prevalent. However, these tests, which primarily assess open kinetic chain movements and isokinetic muscle actions, often prove economically impractical. Yet, athletic activities typically involve closed kinetic chain movements, rapid muscle actions, and the stretch-shortening cycle, necessitating the selection of appropriate evaluation methods to assess athlete performance (20).

The primary objective of this research is to assess the strength of hip muscle groups that exert the greatest

influence on JH, impact force upon landing, knee stability, and running speed in professional athletes. A review of the existing literature no studies found that conducted an anatomical and biomechanical comparison of this specific topic. By evaluating the strength of the right hip extensor (HER), left hip extensor (HEL), right hip flexor (HFR), left hip flexor (HFL), right hip abductor (HABR), left hip abductor (HABL), right hip adductor (HADR), and left hip adductor (HADL) in relation to JH, impact force upon landing, knee stability, and running speed, this study aims to identify which muscle group significantly impacts these variables. The findings of this investigation will provide valuable insights and contribute to the literature by enabling more informed prescriptions of strength training for athletes with suboptimal performance, thereby enhancing their athletic capabilities.

Materials and Methods

Design and Study Participants

The study focused on elite athletes who sought services at the Sportoteam Athlete and Spinal Health Center between 2020 and 2024 and had measurements taken using Vald Performance Analysis Systems. Ethics approval was obtained through a decision of the University of Health Sciences Türkiye, Hamidiye International Faculty of Medicine Ethics Committee dated: 13.06.2026 (meeting number: 2024/7; decision number: 7/3). We certify that the study was performed in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants, ensuring voluntary participation and understanding of the study's purpose and procedures. Demographic data, including age and gender, were collected from the athletes' archival files prior to data recording. Inclusion criteria stipulated that athletes should be aged between 16 and 20, possess elite status, and have undergone analysis with Vald Performance Force Systems. Conversely, exclusion criteria were applied to athletes who were below 16 or above 20 years old, did not meet elite athlete status, or had not been analyzed with Vald Performance force systems. Hip strength measurements using the Vald Performance system were conducted under standardized conditions as follows: adductor and abductor muscle strength were measured isometrically in the supine position with the knees flexed; hip extension strength was measured isometrically in the prone position with the knees flexed at 90°; and hip flexion strength was measured isometrically in the supine position with both the hip and the knee positioned at 90°. Hip adduction, hip extension, and hip flexor strength were measured with the ForceFrame device. JH, PP, and relative strength index (RSI)-modified values from the countermovement jump test were measured using the ForceDecks device (Figure 1).

Statistical Analysis

Power analysis was conducted to determine the sample size, with a type 1 error rate set at 0.05 and a statistical power of 0.80, resulting in a required sample size of 34 subjects. G*Power software version 3.1.9.4 facilitated this analysis. Subsequently, the normality of the data distribution was verified, and the Pearson correlation test was employed.

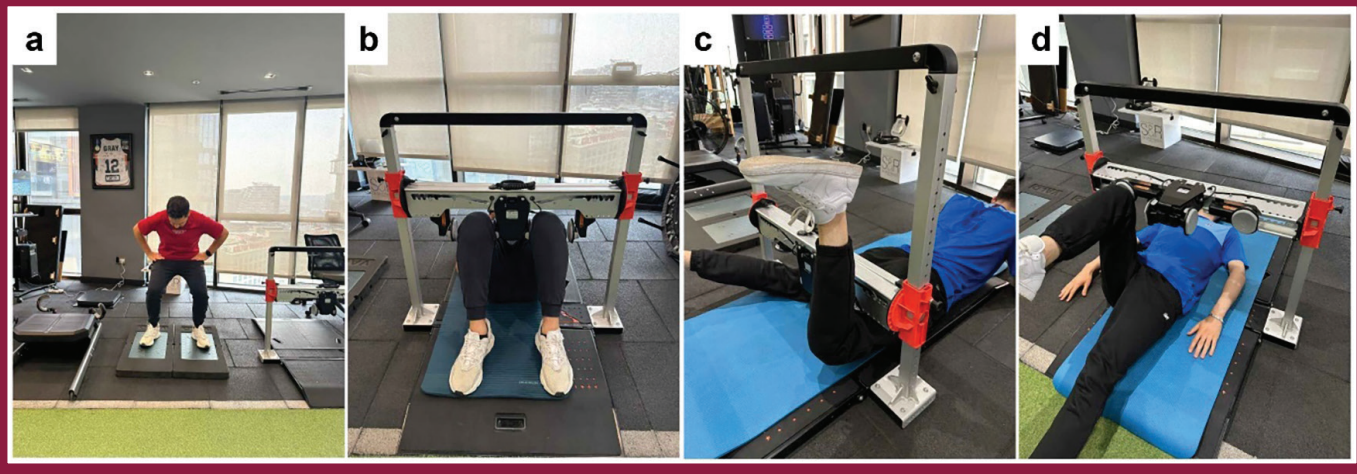


Figure 1. ForceFrame and ForceDecks devices to measure HER, HEL, HFR, HFL, HADL HABR, and HABL strength, and to assess JH, PP, and RSI-modified values. (a) JH, PP, and RSI-modified values were measured using a countermovement jump test with a ForceDecks device. (b) HADR and HADL were measured with the ForceFrame device. (c) HER and HEL were measured with the ForceFrame device. (d) HFR and HFL were assessed using the ForceFrame device. HER, right hip extensor; HEL, left hip extensor; HFR, right hip flexor; HFL, left hip flexor; HADR, right hip adductor; HADL, left hip adductor; HABR, right hip abductor; HABL, left hip abductor; JH, jump height; PP, peak power; RSI, reactive strength index.

Additionally, linear regression analyses were performed to identify the influential factors. Continuous variables derived from these analyses were presented as means and standard deviations (SDs). The statistical significance threshold was set at 0.05, and data were analyzed using IBM SPSS Statistics, version 27.0 (IBM Corp., Armonk, NY, USA).

Results

Study Sample

34 elite male athletes aged 15-17 years were recruited from the Sportoteam Athlete and Spinal Health Center. The athletes' mean ± SD age was 17.12 ± 1.09 years. 24 (70.6%) of the athletes were right-leg dominant and had hamstring asymmetry.

Correlation Analysis

Significant associations were identified among JH, HER, and HFL ($p < 0.05$). Additionally, significant correlations were observed between PP and HER ($p < 0.05$). A notable correlation was found between RSI and HER ($p < 0.05$). Moreover, a significant relationship was detected between RPA and HER ($p < 0.05$) (Table 1).

Linear Regression Analysis

Our simple linear regression analyses revealed that HER and HFL significantly influenced JH ($p < 0.05$). Additionally, HER was a significant predictor of PP ($p < 0.05$). Furthermore, HER had a substantial effect on the RSI ($p < 0.05$). However, HER was found to have a significant negative impact on RPA ($p < 0.05$) (Table 2 and Figure 2). No significant relationships were observed between dominant-side hip and hamstring muscle strengths and performance outcomes, including JH, PP and RSI ($p > 0.05$).

Table 1. Correlation analysis between hip muscle strength and athletic performance metrics.

Correlation Pearson r	95% confidence intervals	Correlation coefficient r	p value
PP vs. HER	0.1500 ~ 0.6938	0.4646	$p < 0.01$
RSI vs. HER	0.2006 ~ 0.7199	0.5046	$p < 0.01$
RPA vs. HER	-0.6474 ~ -0.06670	-0.3959	$p < 0.05$
JH vs. HER	0.1689 ~ 0.7037	0.4796	$p < 0.01$
JH vs. HFL	0.006726 ~ 0.6112	0.3441	$p < 0.05$

JH, jump height; HER, hip extension right strength; HFL, hip flexor left strength; PP, peak power; RPA, reactive pro agility; RSI, relative strength index.

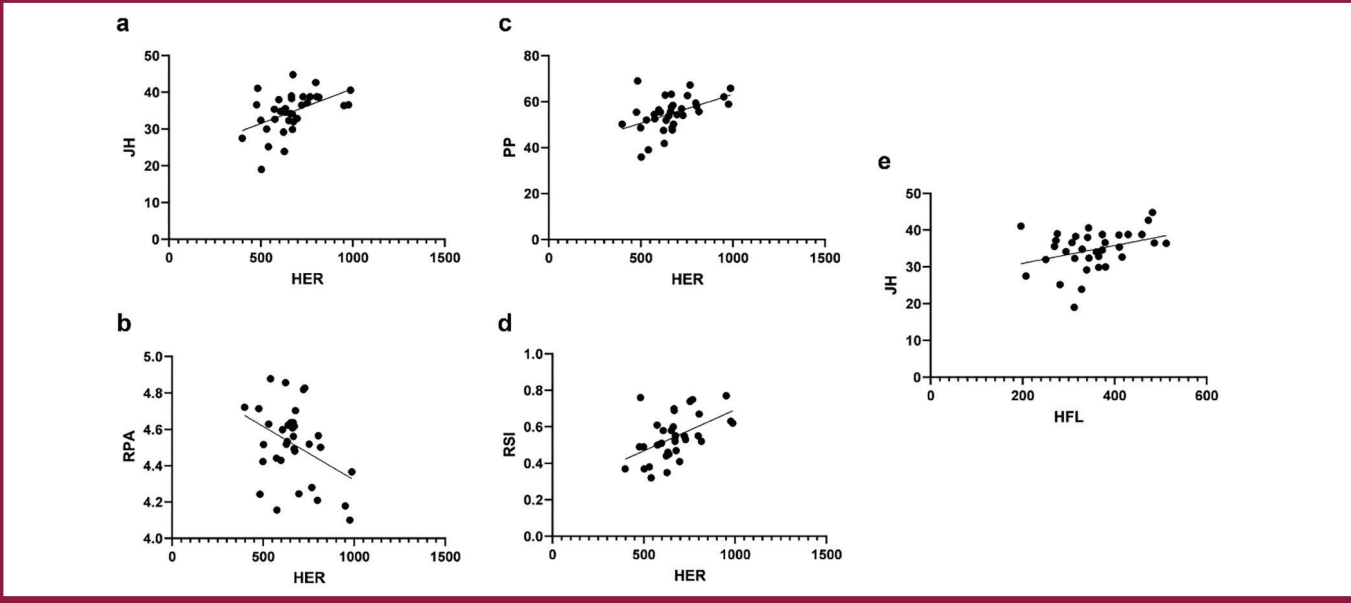


Figure 2. Linear regression analysis indicated that HER and HFL significantly influenced JH, RPA, PP, and RSI. Significant effects of HER on JH (a), RPA (b), PP (c), and RSI (d) were detected. A significant influence of HFL on JH (e) was also observed. HER, right hip extensor; HFL, left hip flexor; JH, jump height; RPA, relative peak acceleration; PP, peak power; RSI, reactive strength index.

Table 2. Linear regression analysis between hip muscle strength and athletic performance metrics.

Dependent (Y)	Independent (X)	Linear regression formula	95% confidence intervals	R^2	p value
PP	HER	Y= 0.02508*X+38.10	0.007867 ~ 0.04230	0.2158	p < 0.01
RPA	HER	Y= -0.0005903*X+4.911	-0.001083 ~ -0.02375	0.1568	p < 0.05
RSI	HER	Y= 0.0004504*X+0.2432	0.0001729 ~ 0.0007280	0.2546	p < 0.01
JH	HER	Y= 0.01895*X+22.05	0.006467 ~ 0.03144	0.2300	p < 0.01
JH	HFL	Y= 0.02422*X+26.13	0.0004236 ~ 0.0463	0.1184	p < 0.05

JH, jump height; HER, hip extension right strength; HFL, hip flexor left strength; PP, peak power; RPA, reactive pro agility; RSI, relative strength index.

Discussion

We found a significant correlation of HER and HABR with JH. However, univariate linear regression analysis indicated that HADL, HER, and HFL significantly influenced JH. These results align with previous research emphasizing the critical role of hip flexors and extensors in generating power during jumping activities. This relationship underscores the importance of these muscle groups in enhancing upward propulsion. For instance, a study by Deane et al. (21) demonstrated that an 8-week hip flexor resistance-training program led to significant improvements in shuttle run and jumping performance, highlighting the contribution of hip flexor strength to explosive movements. Similarly, research by Tsiokanos et al. (22) found a significant positive relationship between jumping height and the isokinetic strength of hip and knee extensors, indicating that these muscle groups are key contributors to jump performance.

Our findings reveal that HER is significantly correlated with RSI. A univariate regression analysis indicated that HABR and HER influenced RSI. These associations with RSI-modified measures suggest that stronger hip extensors may enable athletes to achieve improved reactive strength, which is crucial for activities that involve rapid transitions between eccentric and concentric muscle actions, such as jumping. The results highlighted the importance of specific hip muscle groups for measures of athletic performance. A study by Anastasiou et al. (23) investigated the correlation between the RSI and isometric rate of torque development with weightlifting performance. The findings suggest that RSI is one of the significant predictors of weightlifting performance, underscoring the importance of reactive strength in explosive athletic activities. Therefore, our study provides valuable evidence linking hip extensor strength and abductor function to performance metrics such as RSI, reinforcing the significance of targeted training for these muscle groups in athletic performance.

Additionally, correlation and univariate analyses indicated significant relationships between hip flexion strength and reactive pro agility (RPA) 5-10-5 seconds. This means that hip muscle strength contributes not only to power generation but also to rapid changes in direction and overall agility. This finding is particularly relevant for sports that require rapid acceleration and deceleration. These results have practical implications for the design of targeted training programs for athletes. The strong correlations between hip muscle strength and key performance outcomes suggest that strengthening both hip flexors and extensors could improve an athlete's JH, reactive strength, and agility. Therefore, incorporating exercises that focus on both hip flexion and extension into training regimens could help address performance deficits and enhance overall athletic capabilities. Our results were consistent with research by Sonoda et al. (24), who found that hip extension training and improved ankle plantar flexion strength were associated with enhanced agility, suggesting that targeted strengthening of these muscle groups can positively impact performance in activities requiring quick directional changes. These results have practical implications for designing targeted training programs for athletes. The strong correlations between hip muscle strength and key performance outcomes suggest that strengthening both hip flexors and extensors could improve an athlete's JH, reactive strength, and agility. Therefore, incorporating exercises that focus on both hip flexion and extension into training regimens could help address performance deficits and enhance overall athletic capabilities.

The present study demonstrated that HER and HFL were significantly associated with performance parameters such as JH, PP, and RSI, whereas no significant relationships were observed for the contralateral counterparts. Although this asymmetrical pattern may initially appear coincidental, growing evidence suggests that athletic performance is strongly influenced by inter-limb asymmetries and neuromuscular coordination strategies rather than unilateral strength alone (25,26). Limb dominance was assessed in our cohort, with 71% of participants identified as right-leg dominant; however, dominant-side strength did not independently predict performance outcomes, consistent with previous findings indicating that dominance is task-specific and not always a determinant of force production (27). In dynamic activities such as jumping, the dominant limb

is often more involved in propulsion, particularly through hip extension, while the non-dominant limb contributes to stabilization and limb repositioning (28). This may explain the significance of HER and HFL in the present study. Furthermore, the presence of asymmetrical hamstring function between limbs may alter force transmission within the posterior chain and affect stretch–shortening cycle efficiency (29). The lack of significant associations for HEL and HFR further supports the interpretation that these findings reflect functional and biomechanical asymmetries rather than random variation. Nevertheless, because neuromuscular activation patterns were not directly assessed, these interpretations should be considered with caution; future studies incorporating electromyographic and kinetic analyses are warranted. The limitations of our study include a small sample size, the inclusion of elite athletes in a narrow age group, and a single-center design. We hope to conduct studies with more participants across a wider age range.

Conclusion

Hip strength showed side-specific associations with performance; HER and HFL contributing to JH, PP, and RSI. These findings suggest that performance depends on inter-limb asymmetry and neuromuscular coordination rather than dominance alone. Asymmetrical hamstring function may underlie these effects. Targeted, side-specific training could enhance performance and reduce imbalances.

Ethics

Ethics Committee Approval: Ethics approval was obtained through a decision of the University of Health Sciences Türkiye, Hamidiye International Faculty of Medicine Ethics Committee dated: 13.06.2026 (meeting number: 2024/7; decision number: 7/3). We certify that the study was performed in accordance with the Declaration of Helsinki.

Informed Consent: Informed consent was obtained from all participants, ensuring voluntary participation and understanding of the study's purpose and procedures.

Footnotes

Authorship Contributions

Surgical and Medical Practices: S.K., H.K., Concept: N.Y., H.K., G.H., Design: N.Y., S.K., H.K., G.H., Data Collection or Processing: N.Y., S.K., H.K., Analysis or Interpretation: G.H., Literature Search: N.Y., S.K., Writing: G.H.

Conflict of Interest: No conflict of interest was declared by the authors.

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