ISSN: 2651-4451 • e-ISSN: 2651-446X

Turkish Journal of Physiotherapy and Rehabilitation

2024 35(2)224-235

Nevriye UNAL-SUZER, PT, MSc[1]
Nihal BUKER, PT, PhD[2]
Akın SUZER, PT, MSc[1]

1 Burdur Mehmet Akif Ersoy University Burdur Vocational School of Health Services, Burdur, Turkey
2 Pamukkale University School of Physical Therapy and Rehabilitation, Denizli, Turkey

Correspondence (İletişim):

Nevriye UNAL-SUZER, PT, MSc
Burdur Mehmet Akif Ersoy University,
Burdur Vocational School of Health Services
İstiklal Yerleşkesi, 15030, Burdur, Turkey
Phone: +90 248 213 31 74
E-mail: nusuzer@mehmetakif.edu.tr
ORCID: 0000-0002-8049-5714

Nihal BUKER
E-mail: nasuk@pau.edu.tr
ORCID: 0000-0001-7259-7983

Akın SUZER
E-mail: akinsuzer@gmail.com
ORCID: 0000-0003-2435-9539

Received: *05.07.2023 (Geliş Tarihi)*
Accepted: *25.04.2024 (Kabul Tarihi)*

EXAMINING THE CORRELATION BETWEEN HIP ADDUCTOR MUSCLE STRENGTH, CORE STABILIZATION, AND LOWER EXTREMITY PERFORMANCE IN HEALTHY INDIVIDUALS

ORIGINAL ARTICLE

ABSTRACT

Purpose: This study aimed to investigate the correlation between hip adductor muscle strength and endurance, core stabilization, and lower extremity performance.

Methods: One hundred thirty-three healthy individuals were included in the study. Bilateral hip adductor muscle strength was evaluated with a compression test by using a sphygmomanometer, and endurance was evaluated by the number of hip adduction repetitions for each extremity performed in the side-lying position in one minute. Core stabilization was evaluated by the endurance of the trunk muscles (the time of maintaining the flexion of the trunk 60 degrees, the lateral bridge position, and the trunk extension against gravity). Lower extremity dynamic balance (Y balance test) and performance (single-leg and triple-crossover hop test) were also evaluated.

Results: A positive and moderate correlation was found between hip adductor muscle strength and endurance of nondominant (r=0.529, p<0.001) and dominant (r=0.355, p<0.001) trunk lateral flexors on the lower extremity side, dominant single-leg hop test (r=0.314, p<0.001), and dominant (r=0.362, p<0.001) and nondominant (r=0.331, p<0.001) triple-crossover hop test. A negative and low level of correlation was found between hip adductor muscle strength and dominant (r=-0.235, p=0.007) and nondominant (r=-0.244, p=0.005) Y balance test total scores, and dominant (r=-0.167, p=0.055) and nondominant (r=-0.186, p=0.032) Y balance test posteromedial scores.

Conclusion: Hip adductor muscle strength and endurance were significantly correlated with core stabilization, lower extremity dynamic balance and performance, and hip adductor muscle strength, balance, and performance test scores were affected by gender.

Keywords: Core Stability, Muscle Strength, Physical Functional Performance

SAĞLIKLI BİREYLERDE KALÇA ADDUKTÖR KAS KUVVETİNİN, KOR STABİLİZASYONU VE ALT EKSTREMİTE PERFORMANSI İLE İLİŞKİSİNİN İNCELENMESİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışmanın amacı, kalça adduktör kas kuvveti ve enduransı ile kor stabilizasyonu ve alt ekstremite performansı arasındaki ilişkiyi araştırmaktı.

Yöntem: Çalışmaya 133 sağlıklı birey dahil edildi. Bilateral kalça adduktör kas kuvveti sfigmomanometre kullanılarak sıkıştırma testi ile, endurans ise her bir ekstremite için yan yatış pozisyonunda bir dakika içinde yapılan kalça adduksiyon tekrar sayısı ile değerlendirildi. Kor stabilizasyon, gövde kaslarının enduransı (gövdenin 60 derece fleksiyonunu, lateral köprü pozisyonunu ve yerçekimine karşı gövde ekstansiyonunu sürdürme süresi) ile değerlendirildi. Alt ekstremite dinamik dengesi (Y denge testi) ve performans (tek ayak ve üç adım çapraz sıçrama testi) değerlendirildi.

Sonuçlar: Kalça adduktör kas kuvveti ile nondominat (r=0,529, p<0,001) ve dominant (r=0,355, p<0,001) alt eksremite tarafındaki gövde lateral fleksörleri enduransları, dominant tek ayak sıçrama testi (r=0,314, p<0,001), dominant (r=0,362, p<0,001) ve nondominant (r=0.331, p<0,001) üç adım çapraz sıçrama testi skorları arasında pozitif yön ve orta düzeyde ilişki bulundu. Kalça adduktör kas kuvveti ile dominant (r=-0.235, p=0.007) ve nondominant (r=-0.244, p=0.005) Y denge testi toplam skorları ve dominant (r=-0.167, p=0.055) ve nondominant (r=-0.186, p=0.032) Y denge testi posteromedial skorları ile negatif yön ve düşük düzeyde ilişki bulundu.

Tartışma: Kalça adduktör kas kuvveti ve enduransı ile core stabilizasyon, alt ekstremite dinamik denge ve performansı arasında anlamlı ilişki bulunmuştur ve kalça adduktör kas kuvveti, denge ve performans test skorları cinsiyetten etkilenmektedir.

Anahtar Kelimeler: Kor Stabilite, Kas Kuvveti, Fiziksel Fonksiyonel Performans

INTRODUCTION

Today, participation in sporting activities has expanded not only to athletes but also to too many participants, with the increase in participants' interest and recreational resources (1). The hip adductors account for approximately 25% of the lower limb muscle volume of healthy adults. Since the proportion of muscle volume is closely related to muscle strength, the muscle strength of the hip adductors is higher than that of other hip muscles. Due to sudden changes in the direction of sports activities and explosive power hip adductor muscles are injured more frequently, and this causes pain (2,3). Apart from sports activities, hip adductor muscles are among the muscles that should be avoided from injuries due to their contribution to lowering extremity stabilization and spine stabilization and their effects on knee biomechanics. Determining the factors associated with the strength of the hip adductor muscles is deemed significant for the prevention of injuries and the planning of rehabilitation programs (4).

Core muscles are the main stabilizer muscles. The endurance and balance of these muscles are related to the entire spine biomechanics. Besides, abnormal pelvic mechanics that can lead to injuries can be prevented by maintaining the strength balance of the lower extremity and core muscles (5). The contractions of the hip adductors are responsible for the adduction movement of the lower limb and are also involved in the control of pelvic movements when body weight is supported by only one lower limb. Furthermore, contractions of the hip adductors facilitate coordination between the pelvic and abdominal muscles. The striated muscles of the urethral wall also contract during contraction of the hip adductor muscles along with the pelvic floor muscles. Contraction of the adductor muscles facilitates synergistic intrapelvic muscle contraction. Considering the correlation between hip adductor muscles and trunk muscles, internal and external obliques work together with hip adductor muscles to provide not only functional movement but also stabilization by connecting to each other in the anterior oblique sling system (6). Although we have already had this information, there are no studies present in the literature, as far as we could review, examining the correlation between hip adductor muscle strength and core stabilization in healthy young individuals.

Evaluating lower extremity performance provides information about the ability to perform advanced activities and sports aptitude (7). Extremity strength and endurance are important components that determine performance power and post-performance injury risk (8). In the research examining the correlation between muscle strength around the hips and functional performance tests, the strongest correlation has been found between performance test scores and hip adductor strength. However, it has been reported that more research is needed on this issue (9).

The hypotheses of this study are as follows;

H1: There is a relationship between hip adductor muscle strength and core stabilization in healthy individuals.

H2: There is a relationship between hip adductor muscle strength and lower extremity performance in healthy individuals.

Based on all these, we aimed to examine the correlation between hip adductor muscle strength and endurance, core stabilization, and lower extremity performance in healthy individuals.

METHODS

Ethics committee approval of this study was obtained from Pamukkale University Non-Interventional Clinical Research Ethics Committee with the committee decision dated 24.12.2019 and numbered 22, and necessary changes were made with the committee decision dated 08.12.2020 and numbered 23. The research was carried out at Burdur Mehmet Akif Ersoy University Burdur Vocational School of Health Services University. The students at the university in the 2019-2020 and 2020-2021 academic years were informed about the research through the school information system and were invited to participate in the research. Informed consent forms were obtained from the participants according to the Declaration of Helsinki, and information was given about the evaluations.

The sample size of our research was determined by the G*Power (3.1.9.2) program. It was planned to include at least 111 participants in our research to achieve 90% power with r=0.27 (10) α=0.05 type I error, β=0.10 type II error.

Inclusion criteria: individuals who are between 18 and 25 years of age; volunteers; who can understand and apply the relevant instructions; and individuals who can speak and understand Turkish were included in the study. Exclusion criteria: subjects with spine and lower extremity injuries or surgery in the last 6 months; individuals who have chronic pain in the spine and lower extremities; individuals who have systemic and chronic diseases; recreational or professional athletes; individuals who have muscle shortness in the lower extremities that affects performance were not included in the study. Individuals who wanted to leave the study voluntarily and individuals who could not complete the assessment content for any reason were excluded from the study. The sampling flow chart of the research is presented in Figure 1.

In the evaluation, the demographic information and dominant lower extremity information of the participants were recorded through a prepared form. Lower extremity dominance was determined by examining the dominant foot while kicking the ball (11). The strength and endurance of hip adductor muscles were evaluated. Static endurance measurements of trunk flexors, extensors, and lateral flexors were performed in evaluating core stabilization. Since it would affect performance, dynamic balance evaluation was performed, and lower extremity performance tests were applied. All the assessments of one participant were made by the same person on the same day. Muscle strength, endurance, dynamic balance, and performance were evaluated with appropriate rest intervals.

Muscle strength

Hip adductor muscles strength measurement*:* The strength of the hip adductor muscles was evaluated by using a sphygmomanometer. Before initiating the evaluation, a pre-test was applied to 45 individuals in order to determine the validity of the sphygmomanometer. Then the measurement for the research was initiated. The sphygmomanometer was fixed at 10 millimeters of mercury (mmHg) while the participant's hips were flexed to approximately 45 degrees, and the soles of the feet were lying on their back on the bed. The cuff of the sphygmomanometer was placed between both knees. The participant compressed the cuff. After the compression, the closest pressure value up to 5 mmHg was measured as the isometric force (12). Each measurement was performed three times, and the mean score of the three measurements was recorded as the score. Hip adductor muscle strength measurement is presented in Figure 2.

Hip adductor muscles endurance measurement*:* In order to measure the dynamic endurance of the adductor muscles, a 20-degree arc with normal hip adduction value was drawn on the wall. The participant was positioned in the side-lying position so that the hip, knee, and ankle joints were in the same line. The participant was asked to perform as many hip adductions as possible within 60 seconds, with the participant's foot on the spring drawn on the wall. The number of adductions performed correctly (reaching the reference line) was recorded for both legs (The clinical test applied for the dynamic endurance measurement of the hip abductor muscles was designed so that it was appropriate for the dynamic endurance measurement of the hip adductor muscles.) (13).

Core stabilization

Trunk flexor muscles endurance assessment: The participant's trunk was positioned in 60° flexion, knees in 90° flexion, with feet fixed on the bed and arms crossed in front. The participant was asked to try to maintain trunk flexion. While continuing the position, the participant was told to breathe without holding their breath (14).

Trunk extensor muscles endurance assessment: The participant was positioned in the prone position so that the pelvis and lower extremities remained on the bed, and the torso hanging from the bed from the anterior superior of the spine iliac. The lower extremity weight was stabilized with the help of the researchers. The participant was instructed to cross their arms forward and lift their torso backward. The participant was also asked to try to maintain trunk extension (14).

Trunk lateral flexor muscles endurance assessment: The participant was positioned on the left side for the right side and on the right side for the left side with the forearm parallel to the bed. When ready, the participant was asked to do a side bridge with support from the elbows and feet.

The tests were terminated as soon as the participant was not able to maintain the test position or when the body oscillations were observed. The time obtained with the stopwatch was recorded in seconds (14).

Lower extremity performance

Dynamic balance measurement (Y balance test): The participant was asked to place their feet in the very center of the test setup. The participant was told to lie down with the other foot in the anterior, posterolateral, and posteromedial directions while standing in balance on one leg. Three trials were performed before initiating the test. The participant was then asked to lie down three times in each direction. The largest distance lying down by the participant was recorded in centimeters. For the total score calculation, the participant's leg length was measured for both extremities. The distance lengths in three directions were summed up. The test score was obtained by dividing the total value by 3 times the leg length of the same side and multiplying it by 100. It is accepted that the higher the score, the better the balance is (15).

Lower extremity performance tests: Performance evaluations were carried out with single-leg hop and triple-crossover hop tests. For both tests, a track with a long vertical line passing through the middle of a horizontal line was used. In the single-leg hop test, the participant jumped on the vertical line with the finger line behind the horizontal line (16). The distance between the heel and the horizontal line was measured. In the triple-crossover hop test, the participant on one foot made triple crossover jumps, crossing the vertical line, on the right or left side of the vertical line, with the finger level behind the horizontal line. The distance between the heel and the horizontal line was measured. Scores were recorded for both legs. It is accepted that the higher the score, the better the performance of the individual is (17).

Statistical Analysis

Statistical analyses were performed with SPSS 24.0 (IBM SPSS Statistics 24, Armonk, NY: IBM Corp.) package program. Continuous variables were expressed as mean ± standard deviation and categorical variables were expressed as numbers and percentages. The Kolmogorov-Smirnov test was used for the normal distribution of the variables examined. The Mann-Whitney U Test was used to compare independent group differences. The Spearman Correlation analysis was used to examine the correlations between continuous variables. $p<0.05$ was considered statistically significant. The correlation coefficient between 0.1-0.29 was considered low, while the correlation coefficient between 0.30-0.49 was considered moderate, the correlation coefficient between 0.50-0.69 was considered high, and the correlation coefficient between 0.70 and above was considered very high (18).

Table 1. Mean Age, Height, Weight, and BMI of the Participants

	Min-Max	X±SD
Age (year)	18-25	20.03±1.15
Height (m)	1.40-1.89	1.67±0.09
Weight (kg)	42-95	61.83±11.94
BMI (kg/m²)	16.94-32.03	22.09±3.14

Data presented as X ± SD, min: minimum, max: maximum, m: meter, kg: kilogram, kg/m²: kilogram/ square meters, BMI: body mass index

Table 2. Values of the Continuous Variables of the Participants

Variables	Min-Max	X±SD
Hip adductor muscles strength (mmHg)	93.33-300	167.47 ± 40
Dominant hip adductors endurance (repetitions)	20-120	52.55 ± 17.59
Nondominant hip adductors endurance (repetitions)	18-112	49.99 ± 16.4
Trunk flexors endurance (sec)	12-600	125.41 ± 109.85
Trunk extensors endurance (sec)	7-156	46.26 ± 27.41
Trunk lateral flexor endurance on the dominant lower extremity side (sec)	2-109	37.63 ± 24.4
Trunk lateral flexor endurance on the nondominant lower extremity side (sec)	2-115	39.43 ± 26.32
Y balance test- dominant anterior (cm)	43-100	60.94 ± 10.47
Y balance test- dominant posteromedial (cm)	13-97	47.97 ± 16.16
Y balance test- dominant posterolateral (cm)	31-100	57.2 ± 12.84
Y balance test- dominant total (cm)	41.92-108.79	64.6 ± 13.92
Y balance test- nondominant anterior (cm)	39-87	60.66 ± 10.69
Y balance test- nondominant posteromedial (cm)	21-97	49.03 ± 16.4
Y balance test- nondominant posterolateral (cm)	34-113	59.29 ± 12.57
Y balance test- nondominant total (cm)	40.56-108.79	65.68 ± 13.68
Dominant single-leg hop test score (cm)	28-134	72.92 ± 22.79
Nondominant single-leg hop test score (cm)	6-148	69.74 ± 23.83
Dominant triple-crossover hop test score (cm)	109-454	228.11 ± 64.13
Nondominant triple-crossover hop test score (cm)	115-453	225.14 ± 63.45

Data presented as X±SD, min: minimum, max: maximum, mmHg: millimeters of mercury, sec: second, cm: centimeter

RESULTS

The mean age of the participants was 20.03±1.15 (18-25) years, and their mean body mass index (BMI) was 22.09±3.14 (16.94-32.03) kg/m2. The number of female participants was 94 (70.7%), whereas the number of male participants was 39 (29.3%). The dominant lower extremity of 121 (91%) participants was right, while the dominant lower extremity of 12 (9%) participants was left (Table 1). The values of the continuous variables of the participants are presented in Table 2.

A positive and moderate level correlation was found between hip adductor muscle strength and dominant (r=0.355, p<0.001) and nondominant (r=0.529, p<0.001) trunk lateral flexor endurance, dominant single leg hop test (r=0.314, p<0.001), and dominant (r=0.362, p<0.001) and nondominant (r=0.331, p<0.001) triple-crossover hop test scores. A positive and low-level correlation was found between hip adductor muscle strength and the nondominant single-leg hop test (r=0.288, p=0.001). Besides, negative and low-level correlations were found between hip adductor muscle strength and dominant Y balance test total score (r=-0.235, p=0.007) and posteromedial score (r=-0.167, p=0.050), nondominant Y balance test total score (r=-0.244, p=0.005) and posteromedial score (r=-0.186, p=0.032), and the difference in the endurance of the trunk lateral flexors between the dominant and nondominant sides (r=-0.247, p=0.004) (Table 3).

A positive moderate-level correlation was found between dominant hip adductor endurance and trunk flexor endurance (r=0.306, p<0.001). Positive and low-level correlations were found between dominant hip adductor endurance and trunk extensor endurance (r=0.189, p=0.029), dominant trunk lateral flexors endurance (r=0.177, p=0.041), and dominant Y balance test posteromedial score (r=0.173, p=0.046). A positive and low-level correlation was found between nondominant hip adductor endurance and trunk flexor endurance (r=0.228, p=0.008), trunk

Table 3. The Correlation between Participants' Hip Adductor Muscle Strength and Core Stabilization, Lower Extremity Balance and Performance

	Hip adductor muscle strength	
Variables	**r**	**p**
BMI	0.174	0.045*
Hip adductor endurance		
Dominant extremity	0.147	0.091
Nondominant extremity	0.157	0.071
Core stabilization		
Endurance of trunk flexors	0.149	0.087
Endurance of trunk extensors	0.036	0.679
Endurance of trunk lateral flexor on the dominant lower extremity side	0.355	0.000*
Endurance of trunk lateral flexor on the nondominant lower extremity side	0.529	0.000*
Dominant Y balance test		
Anterior	-0.131	0.132
Posteromedial	-0.167	0.050*
Posterolateral	-0.088	0.313
Total score	-0.235	0.007*
Nondominant Y balance test		
Anterior	-0.162	0.062
Posteromedial	-0.186	0.032*
Posterolateral	-0.081	0.353
Total score	-0.244	0.005*
Lower Extremity Performance		
Dominant single-leg hop test	0.314	0.000*
Nondominant single-leg hop test	0.288	0.001*
Dominant triple-crossover hop test	0.362	0.000*
Nondominant triple-crossover hop test	0.331	0.000*
Dominant vs. Nondominant Differences		
Endurance difference of trunk lateral flexors	-0.247	0.004*

Spearman correlation analysis r= correlation coefficient, p= significance value, *p<0.05 statistically significant difference, BMI: body mass index

extensor endurance (r=0.185, p=0.033), and dominant (r=0.218, p=0.012) and nondominant (r=0.199, p=0.022) trunk lateral flexor endurance (Table 4). The comparisons of hip adductor muscle strength, lower extremity balance, and performance scores according to gender are shown in Table 5.

DISCUSSION

In our research, in which we aimed to examine the correlation between hip adductor muscle strength, core stabilization, lower extremity dynamic balance, and performance in healthy individuals, a correlation was found between trunk lateral flexor endurance and hip adductor muscle strength and endurance. Besides, a correlation was observed between trunk flexor and extensor endurance and hip adductor endurance. Correlations were also revealed between posteromedial and total score of dynamic balance and hip adductor strength and endurance and between lower extremity performance and hip adductor muscle strength.

Many studies have included the relationship between BMI and lower extremity muscle strength. Although there was a negative relationship between BMI and lower extremity muscle strength in studies that included obese and normal BMI

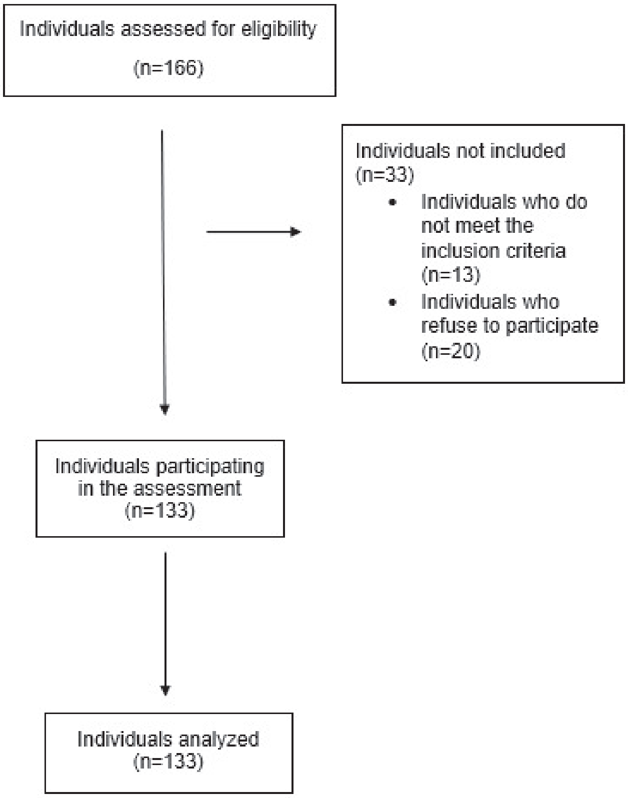

Figure 1. The Sampling Flow Chart of the Research

individuals and examined the relationship between BMI and lower extremity muscle strength, in a study that included young and healthy participants with a BMI of 35 and below and a positive correlation was found between BMI and lower extremity muscle strength. (19,20,21). Our study was also performed with a young and similar population with a mean BMI of 22.09±3.14 kg/m^2, and a positive correlation was found between hip adductor muscle strength and BMI. Similar to the results of the study mentioned above, the fact that our population had normal BMI values may have caused this conclusion.

Hip adduction increases oblique muscle activity and isometric contraction of adductor muscles facilitates contralateral oblique muscle function through the muscle sling system (22). Probably because of this, in our research, we observed a correlation between trunk lateral flexor endurance and hip adductor muscle strength and endurance. Hip adductor muscle strength and endurance may have a significant role in the lateral stabilization of the trunk. Therefore, hip adductor strength and endurance should also be considered in cases associated with a lack of lateral stabilization and thus, should be included in the rehabilitation program.

It has been reported that imbalances and deficits in core muscles will cause increased fatigue, decreased lower extremity endurance, and increased risk of injury (23). Our research found a negative correlation between the dominant and nondominant difference in trunk lateral flexor endurance and hip adductor muscle strength. Although this correlation is low it suggests that hip adductor muscle strength may be adversely affected as the difference between the dominant and nondominant sides increases, that is to say, as an imbalance occurs in the trunk muscles.

It has been shown that the contraction of hip adductor muscles during different exercises such as bridge and sling exercises increases the activation of muscles such as transversus abdominus, multifidus, and erector spina in healthy young individuals (24). We found a correlation

Table 4. The Correlation between the Participants' Dominant and Nondominant Hip Adductor Endurance and Core Stabilization, Lower Extremity Balance and Performance

	Dominant hip adductor endurance		Nondominant hip adductor endurance	
Variables	**r**	**p**	**r**	**p**
Core stabilization				
Endurance of trunk flexors	0.306	0.000*	0.228	0.008*
Endurance of trunk extensors	0.189	0.029*	0.185	0.033*
Endurance of trunk lateral flexor on the dominant lower extremity side	0.177	0.041*	0.218	0.012*
Endurance of trunk lateral flexor on the nondominant lower extremity side	0.155	0.074	0.199	0.022*
Dominant Y balance test				
Anterior	0.044	0.613	0.021	0.811
Posteromedial	0.173	0.046*	0.107	0.221
Posterolateral	0.141	0.105	0.089	0.311
Total score	0.112	0.198	0.067	0.442
Nondominant Y balance test				
Anterior	0.121	0.165	0.070	0.422
Posteromedial	0.156	0.072	0.104	0.206
Posterolateral	0.125	0.151	0.024	0.781
Total score	0.130	0.136	0.067	0.445
Lower Extremity Performance				
Dominant single-leg hop test	0.133	0.127	0.158	0.068
Nondominant single-leg hop test	0.059	0.502	0.099	0.256
Dominant triple-crossover hop test	0.094	0.280	0.060	0.496
Nondominant triple-crossover hop test	0.019	0.826	-0.006	0.949

Spearman correlation analysis r= correlation coefficient, p= significance value, *p<0.05 statistically significant difference

between dominant and nondominant hip adductor endurance and trunk extensor endurance in our research. In this case, hip adduction exercises performed simultaneously with trunk extension exercises may facilitate the function of trunk extensors. It may be beneficial for them to take part in exercise programs together.

The plank exercise with unilateral and bilateral hip adduction increases the activation of the rectus abdominis and oblique abdominals (25). Besides, another study mentions a synergy connecting the muscles of the internal oblique, transversus abdominis, rectus femoris, and hip adductors. It has been stated that this synergy deteriorates after an intervention that causes fatigue, such as taking a sidestep, and accordingly, a decrease in hip control function may occur (26). In our research, we found a correlation between dominant and nondominant hip adductor endurance and trunk flexor endurance. Adding hip adduction activity to exercises focusing on improving core stabilization such as plank may increase the effectiveness of the exercise. Also, improving hip adductor endurance can increase the effectiveness of the exercise.

Balanced lower extremity motor activities are associated with lower extremity performance (27). Y balance test, one of the dynamic balance tests, imitates the functional activities of daily life quite well. It also provides a better analysis of bilateral postural control asymmetry, injury risk, or post-injury damage (28). In the research examining the correlation between lower extremity strength and dynamic balance in patients who had had an operated ankle fracture six months before; a correlation was reported between hip adductor muscle strength and anterior, posteromedial, and posterolateral balance in the intact

Table 5. Muscle Strength, Lower Extremity Balance, and Performance Comparisons by Gender

Variables	Min-Max	X±SD	p
Hip adductor muscle strength (mmHg)			
Female	93.33-216.66	154.15±27.21	0.000*
Male	106.66-300	199.57±47.43	
Dominant hip adductor muscle endurance (repetitions)			
Female	20-88	51.58±14.41	0.329
Male	23-120	54.87±23.64	
Nondominant hip adductor muscle endurance (repetitions)			
Female	20-91	49.97±14.52	0.929
Male	18-112	49.79±20.34	
Dominant Y balance test score (cm)			
Female anterior score	43-84	60.15±10.44	0.177
Male anterior score	47-100	62.85±10.43	
Female posteromedial score	13-88	47.09±16.20	0.335
Male posteromedial score	20-97	50.08±16.08	
Female posterolateral score	33-89	56.07±12.08	0.131
Male posterolateral score	31-100	59.90±14.30	
Female total score	42.57-97.86	65.94±13.68	0.741
Male total score	41.92-108.79	65.07±13.86	
Nondominant Y balance test score (cm)			
Female anterior score	39-87	60.09±11.03	0.131
Male anterior score	45-87	62.02±9.83	
Female posteromedial score	21-94	48.08±16.37	0.304
Male posteromedial score	28-97	51.31±16.46	
Female posterolateral score	34-90	57.52±11.70	0.011*
Male posterolateral score	45-113	63.54±13.69	
Female total score	40.56-97.78	65.01±13.85	0.598
Male total score	45.98-108.79	63.61±14.22	
Dominant single-leg hop test score (cm)			
Female	28-130	66.91±20.15	0.000*
Male	40-134	87.41±22.50	
Nondominant single-leg hop test score (cm)			
Female	6-123	62.89±19.42	0.000*
Male	32-148	86.26±25.58	
Dominant triple-crossover hop test score (cm)			
Female	109-373	207.45±48.59	0.000*
Male	155-454	277.90±70.06	
Nondominant triple-crossover hop test score (cm)			
Female	115-366	203.76±48.71	0.000*
Male	127-453	276.69±65.71	

The Mann-Whitney U Test analyzed, data presented as X ± SD, min: minimum, max: maximum, mmHg: millimeters of mercury, cm: centimeter, p= significance value, *p<0.05 statistically significant difference

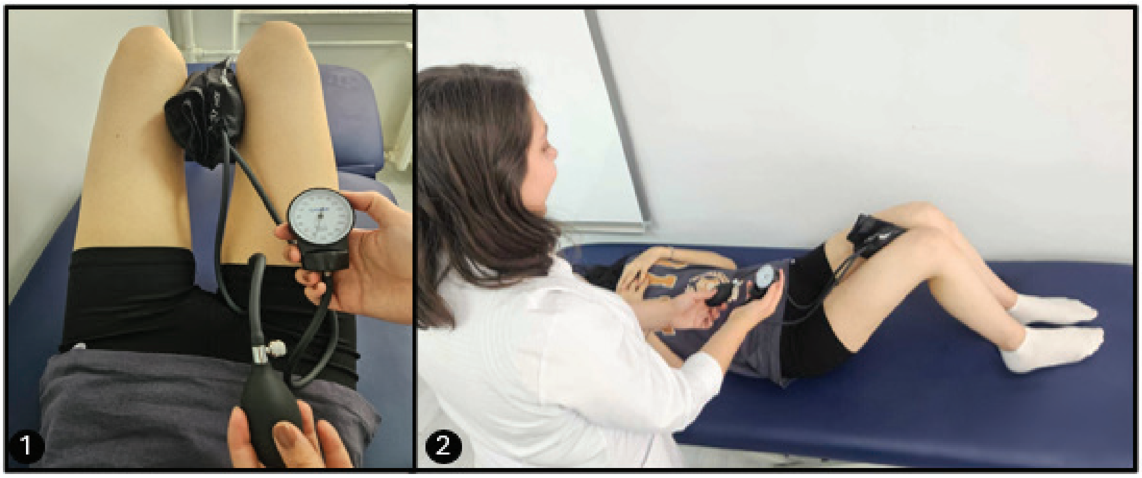

Figure 2. Strength Measurement of the Hip Adductor Muscles.

1) Starting position 2) Compression moment

extremity. It has been stated that this may be due to the involvement of hip adductor muscles in hip flexion and extension movements (29). In our research, we observed a negative correlation between posteromedial and total balance scores and hip adductor strength and endurance. This negative correlation has not been previously reported in the literature. This situation may be caused by other components (such as height, leg length, and the flexibility of the contractile and non-contractile structures of the lower extremities and trunk) on which the dynamic balance is affected. Just as in our research, low correlations were reported between balance and lower extremity muscle strength in children, adolescents, young, middle-aged, and old adults in a review and meta-analysis (30). In our study, we found a significant difference between the dominant and nondominant sides in the Y balance test posterolateral, posteromedial, and total scores. This is thought to support the literature (31,32) stating that balance is affected by dominance. The fact that the total score of the dominant side is higher than that of the nondominant side may also indicate that the ability.

Functionality is a term that is widely used in the clinic and that includes reaching a goal as a result of movement but does not have a standard form for this reason there is no standard for evaluating functionality. But functional performance is evaluated with the help of tests to embody physical abilities and to identify activity-specific disorders. (33,34). In the research examining the correlation between the strength of the muscles around the hip and functional performance tests, the strongest correlation was found between the triple-crossover hop test and the hip adductor peak strength (9). In our research, we found a correlation between hip adductor muscle strength and hop test scores. In this case, we suggest that hip adductor strength should not be ignored in exercise programs designed for functional performance improvement in athletes or when returning to normal function after an injury.

Differences in lower extremity strength and kinematics between genders have been the subject of many studies (35,36). Among the results reported in studies are that especially sagittal plane movements are affected by gender differences (37), males show better aerobic and musculoskeletal system performance than females, and females have lower hip abductor and external rotator muscle strength than males (35). In our study, hip adductor muscle strength and lower extremity performances were found to be higher in males than in females by the literature. The higher muscle strength of males may have caused them to be more skillful in performance tests, to generate more explosive power required for jumping, and to elicit balance reaction responses more easily.

The strengths of our study are that it is one of the few studies investigating the correlation between hip adductor muscle strength, core stabilization, and lower extremity performance in healthy individuals. In our study, all assessments were performed by the same researcher in an environment where the assessments were prepared. In our research, all the evaluations were made by the same researcher in an environment prepared by the evaluations.

The limitation of our research; was the distribution of the students in Burdur Mehmet Akif Ersoy University Burdur Vocational School of Health Services, which is the population of our research, was not equal by gender, and the female population was higher. In other words, while the number of female participants in our research was 94, the number of male participants was 39. This situation is thought to have created several inequalities according to gender in our research.

There is no research on the parameters related to hip adductor muscle strength in the young and healthy population (except for athletes). In this research, we aimed to reveal the correlation between hip adductor strength, core stabilization, and lower extremity performance in this population. Hip adductor muscle strengthening exercises may be included in the exercise programs applied to improve core stabilization and lower extremity performance in healthy individuals. Besides, there is a need to examine the correlation between hip adductor muscle strength and core stabilization in different musculoskeletal system problems. Hip adductor strengthening exercises can contribute to increasing the stabilization of individuals with stabilization problems more effectively. In addition to the performance tests used in the evaluation of athletes, including hip adductor muscle strength to the evaluations may also reveal the correlation between adductor muscle strength and performance in athletes. It may also be beneficial in terms of the efficiency of sports performance, and the prevention of lower extremity injuries can contribute to the planning of post-injury rehabilitation and reinjury prevention programs.

Sources of Support: There is no source of support.

Conflict of Interest: There is no conflict of interest.

Author Contributions: Concept and design Nevriye UNAL-SUZER, Nihal BUKER and Akın SUZER; supervision Nihal BUKER; data collection Nevriye UNAL-SUZER and Akın SUZER; analysis Nihal BUKER; literature review and article writing Nevriye UNAL-SUZER; critical review Nihal BUKER.

Explanations: It is a publication produced from the Master's thesis prepared by Nevriye UNAL-SUZER under the supervision of Nihal BUKER within the scope of the Pamukkale University Health Sciences Institute Physiotherapy and Rehabilitation Master's Program. No paper presentation was made.

Acknowledgment: We would like to thank Burdur Mehmet Akif Ersoy University Burdur Vocational School of Health Services for the technical opportunities they provide

REFERENCES

1. Roux AVD, Evenson KR, McGinn AP, Brown DG, Moore L, Brines S, et al. Availability of recreational resources and physical activity in adults. Am J Public Health. 2007;93(3):493-499.
2. Crockett M, Aherne E, O'Reilly M, Sugrue G, Cashman J, Kavanagh E. Groin pain in athletes: A review of diagnosis and management. Surg Technol Int. 2015;26:275-282.
3. Esteve E, Rathleff MS, Bagur-Calafat C, Urrútia G, Thorborg K. Prevention of groin injuries in sports: A systematic review with meta-analysis of randomized controlled trials. Br J Sports Med. 2015;49(12):785-791.
4. Nicholas SJ, Tyler TF. Adductor muscle strains in sport. Sports Med. 2002;32(5):339-344.
5. Nicola TL, Jewison DJ. The anatomy and biomechanics of running. Clin Sports Med. 2012;31:187–201.
6. Magee DJ. Orthopedic Physical Assessment, 6th ed. St. Elsevier, St. Louis. 2014.
7. Mcgrath TM, Waddington G, Scarvell JM, Ball NB, Creer R, Woods K, et al. The effect of limb dominance on lower limb functional performance--a systematic review. J Sports Sci. 2016;34(4):289-302.
8. Suchomel TJ, Nimphius S, Stone MH. The importance of muscular strength in athletic performance. Sports Med. 2016;46(10):1419-1449.
9. Kollock R, Van Lunen BL, Ringleb SI, Oñate JA. Measures of functional performance and their association with hip and thigh strength. J Athl Train. 2015;50(1):14-22.
10. Kea J, Kramer J, Forwell L, Birmingham T. Hip action-adduction strength and one-leg hop tests: test-retest reliability and relationship to function in elite ice hockey players. J Orthop Sports Phys Ther. 2001;31(8):446-45.
11. Van Melick N, Meddeler BM, Hoogeboom TJ, Nijhuis-van der Sanden MW, van Cingel RE. How to determine leg dominance:

The agreement between self-reported and observed performance in healthy adults. PloS one. 2017;12(12):e0189876.
12. Buchheit MM, Wallace J, Bode M, Poulos N. Monitoring post-match lower-limb recovery in elite Australian Rules Football using a groin squeeze strength test. Sport Perf Sci Rep. 2017;7:1-3.
13. Van Cant J, Dumont G, Pitance L, Demoulin C, Feipel V. Test-retest reliability of two clinical tests for the assessment of hip abductor endurance in healthy females. IJSPT. 2016;11(1):24-33.
14. Huxel Bliven KC, Anderson BE. Core stability training for injury prevention. Sports Health. 2013;5(6):514-522.
15. Kramer TA, Sacko RS, Pfeifer CE, Gatens DR, Goins JM, Stodden DF. The Assciation Between The Functional Movement Screentm, Y-Balance Test and Physical Performance Tests In Male and Female High School Athletes. Int J Sports Phys Ther. 2019 Dec;14(6):911-919.
16. Myers BA, Jenkins WL, Killian C, Rundquist P. Normative data for hop tests in high school and collegiate basketball and soccer players. Int J Sports Phys Ther. 2014 Oct;9(5):596-603.
17. Smith J, De Phillipo N, Azizi S, McCabe A, Beverine C, Orendurff M, et al. The lower extremity grading system (legs) to evaluate baseline lower extremity performance in high school athletes. Int J Sports Phys Ther. 2018 Jun;13(3):401-409.
18. Green SB, Salkind NJ, Akey TM. Methods for controlling type I error across multiple hypothesis tests. In: Using SPSS for Windows. Analyzing and Understanding Data. Upper Saddle River, NJ: Practice Hall. 2000;395–396.
19. Bonney E, Ferguson G, Smits-Engelsman B. Relationship between body mass index, cardiorespiratory and musculoskeletal fitness among South African adolescent girls. Int J Environ Res Public Health. 2018;15(6):1087-1099.
20. Chang CM, Hwang FM, Chi SC. The association between body mass index and physical fitness of normal weight/overweight/obese university students. Int J Environ Res Public Health. 2020;17(15): 5391-5409.
21. Bazett-Jones DM, Cobb SC, Joshi MN, Cashin SE, Earl JE. Normalizing hip muscle strength: establishing body-size-independent measurements. Arch Phys Med Rehabil. 2011;92(1):76-82.
22. Kang MH, Kim SY, Kang MJ, Yoon SH, Oh JS. Effects of isometric hip movements on electromyographic activities of the trunk muscles during plank exercises. J Phys Ther. 2016;28(8):2373-2375.
23. Rivera CE. Core and lumbopelvic stabilization in runners. Phys Med Rehabil Clin N Am. 2016;27(1):319-337.
24. Lee D, Park J, Lee S. Effects of bridge exercise on trunk core muscle activity with respect to sling height and hip joint abduction and adduction. J Phys Ther Sci. 2015;27(6):1997-1999.
25. Kim SY, Kang MH, Kim ER, Jung IG, Seo EY, Oh JS. Comparison of EMG activity on abdominal muscles during plank exercise with unilateral and bilateral additional isometric hip adduction. J Electromyogr Kinesiol. 2016;30:9-14.
26. Matsunaga N, Aoki K, Kaneoka K. Comparison of modular control during side cutting before and after fatigue. Appl Bionics Biomech. 2021;2021:8860207
27. Kafri M, Hutzler Y, Korsensky O, Laufer Y. Functional performance and balance in the oldest-old. J Geriatr Phys Ther. 2019;42(3):183-188.
28. Fusco A, Giancotti GF, Fuchs PX, Wagner H, da Silva RA, Cortis C. Y balance test: Are we doing it right?. J Sci Med Sport. 2020;23(2):194-199.
29. Salas-Gomez D, Fernandez-Gorgojo M, Sanchez-Juan P, Bercero EL, Perez-Núñez MI, Barbado D. Quantifying balance deficit in people with ankle fracture six months after surgical intervention through the Y-Balance test. Gait Posture. 2022;95:249-255.
30. Muehlbauer T, Gollhofer A, Granacher U. Associations between measures of balance and lower-extremity muscle strength/power in healthy individuals across the lifespan: a systematic review and meta-analysis. Sports Med. 2015;45(12):1671-1692.
31. Pereira C, Silva RAD, de Oliveira MR, Souza RD, Borges RJ,Vieira ER. Effect of body mass index and fat mass on balance force platform measurements during a one-legged stance in older adults. Aging Clin Exp Res. 2018;30:441–447.
32. Riemann BL, Davies GJ. Limb, sex, and anthropometric factors influencing normative data for the biodex balance system SD athlete single leg stability test. Athl Train Sports Health Care 2013;5:224–232.
33. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function - part 1. Int J Sports Phys Ther. 2014;9(3):396-409.
34. Kivlan BR, Carcia CR, Clemente FR, Phelps AL, Martin RL. Reliability and validity of functional: performance tests in dancers with hip dysfunction. Int J Sports. 2013;8(4):360-369.
35. Palomino-Devia C, González-Jurado JA, Ramos-Parraci CA. Body composition and physical fitness in Colombian high school students from Ibague. Biomédica. 2017;37(3):408-415.
36. Hannigan JJ, Osternig LR, Chou LS. Sex-Specific Relationships between hip strength and hip, pelvis, and trunk kinematics in healthy runners. J Appl Biomech. 2018;34(1):76-81.
37. Dwyer MK, Boudreau SN, Mattacola CG, Uhl T L, Lattermann C. Comparison of lower extremity kinematics and hip muscle activation during rehabilitation tasks between sexes. J Athl Train. 2010;45(2):181-190.