August 2017

Hip Adduction: Abduction Ratio Differences Between Collegiate Male and Female Soccer Players

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HIP ADDUCTION: ABDUCTION RATIO DIFFERENCES BETWEEN COLLEGIATE MALE AND FEMALE SOCCER PLAYERS

By

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Bachelor of Science - Athletic Training
West Chester University of Pennsylvania
2014

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science – Kinesiology

Department of Kinesiology and Nutrition Sciences
School of Allied Health Sciences
The Graduate College

University of Nevada, Las Vegas
August 2017

Thesis Approval

The Graduate College
The University of Nevada, Las Vegas

July 25, 2017

This thesis prepared by

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entitled

Hip Adduction: Abduction Ratio Differences Between Collegiate Male and Female Soccer Players

is approved in partial fulfillment of the requirements for the degree of

Master of Science – Kinesiology
Department of Kinesiology and Nutrition Sciences

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Abstract

Hip Adduction: Abduction Ratio Differences Between Collegiate Male and Female Soccer Players

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Context: Soccer is a high-intensity sport resulting in injuries. Strength ratios have been used to identify areas of weakness and help prevent further injuries. **Objective:** The purpose of this study was to determine if there was a difference in hip adduction: abduction ratios in collegiate male and female soccer players. The hypothesis was that males will have a lower ratio than females. **Design:** Cohort Study. **Setting:** Research Center. **Participants**: Five male and nine female NCAA Division 1 soccer players were recruited for this study. **Intervention:** Independent variable is gender. Biodex Isokinetic Dynamometer was used for data collection. The subjects performed three practice repetitions at 60°/s to become familiar with the speed and movement required for data collection. Following the practice repetitions, the subject performed one set of five repetitions at 60°/s. The dominant side was collected first followed by the non-dominant side. **Main Outcome Measures:** The dependent variable is hip adduction: abduction ratio. The data was analyzed using SPSS. Descriptive statistics were taken for age, height, and body mass. Independent t-test was used to determine if there was a significant difference in hip adduction and hip abduction peak torques and hip adduction: abduction ratios between male and female soccer players. Data was normalized and independent t-tests was used to determine if a significant difference was found in hip peak torques. Pearson's correlation was used to determine if there was a significant correlation between body mass and hip adduction and abduction strength. **Results:** Males produced a significantly greater hip abduction peak torques in dominant (105.06 ± 17.94 ft-lb) and non-dominant (102.16 ± 18. 68 ft-lb) limbs than females (dominant, 69.2 ± 10.40 ft-lb; non-dominant, 72.57 ± 14.30 ft-lb) for both dominant ($p<0.001$) and non-

dominant ($p=0.01$) limbs. Absolute hip adduction torque was not significantly different between males (dominant: 45.74 ± 17.62 ft-lb, non-dominant: 43.54 ± 17.75 ft-lb) and females (dominant: 26.99 ± 6.71 ft-lb, non-dominant: 35.58 ± 11.81 ft-lb) (dominant, $p=0.08$; non-dominant, $p=0.33$). There was no significant difference in hip adduction: abduction ratio between male and female soccer players in dominant (female: 38.88% ± 6.63%, male: 46.87% ± 25.37%, $p=0.52$) and non-dominant (female: 48.46% ± 10.75%, male: 43.85% ± 21.14%, $p=0.59$). A positive correlation was seen in absolute hip abduction strength and body mass in the population as a whole (abduction dominant: $r=0.769$, $p<0.001$; abduction non-dominant: $r=0.713$, $p=0.004$). When scaled to body mass, there was no significant difference in hip adduction for dominant (female: 0.46 ± 0.13 Nm/kg, male: 0.58 ± 0.25 Nm/kg, $p=0.37$) and non-dominant (female: 0.60 ± 0.22 Nm/kg, male: 0.54 ± 0.24 Nm/kg, $p=0.66$) and in abduction for dominant (female: 1.16 ± 0.23 Nm/kg, male: 1.30 ± 0.16 Nm/kg, $p=0.28$) and nondominant (female: 1.22 ± 0.27 Nm/kg, male: 1.26 ± 0.17 Nm/kg, $p=0.77$) between genders. There was not a significant correlation between body mass and hip strength scaled to body mass (abduction dominant: $r=0.115$, $p=0.70$, abduction non-dominant: $r=-0.014$, $p=0.96$; adduction dominant: $r=-0.011$, $p=0.97$, non-dominant $r=-0.357$, $p=0.21$). **Conclusion:** Gender does not play a role in hip adduction: abduction ratio. **Word Count:** 524

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Chapter 1: Introduction

Soccer is among one of the most popular sports played around the world by both males and females.[1,2] This sport involves high-intensity, intermittent exercise performed at maximum speed paired with functional activities.[3,4,5] Similar to other high-intensity sports, injuries are common in soccer, with 50-80% of the injuries occurring at the lower extremity.[6,7,8]

Injury presentation at the collegiate level is similar between the genders, as sprains and strains are the most common injuries to both male and female in Division III soccer athletes, at 33.4% and 28.7%, respectively.[9] In Division III soccer players, injuries to the thigh are the most common injury site in both male and female soccer players.[9] Specifically, strains of the thigh (17%) or groin (8%) are approximately one-fourth of all soccer injuries.[10,11,12] In male soccer players, groin strains have been reported to occur at a rate of 1.0-1.1 injuries per 1000 playing hours[13,14] and general groin injuries at a rate of 10 to 18 per 100 playing hours.[15,16]

As a player develops their soccer skill set, a preferred leg (dominant) and nonpreferred leg (non-dominant) is established based upon preference to perform different soccer skills; the dominant leg is used for the functional demands of the sport such as kicking, receiving a ball and shooting.[17,18] Bilateral strength differences could be associated with the nature of the sport being that one leg is preferred to kick, receive, and push off to head the ball while the other is used for stability.[18] A contralateral strength difference of 10% or greater has been theorized to contribute to increased injury risk.[19,20] Ekstrand and Gilchrist[1] found that 67% of the injured soccer players had one or more deficits, strength or flexibility, compared to uninjured players in their musculoskeletal profile.

Previous investigations on the strength relationship of the hip adduction and abduction muscle groups have been completed in hockey athletes[12], professional rugby players[21], and soccer players,[22,23] all of which have been evaluated in male athletes. Prendergast et al.[23]

compared hip adduction and abduction strength between dominant and non-dominant limb in Australian footballers. Results concluded that there was no difference in hip strength between dominant and non-dominant limbs. They also investigated hip adduction: abduction ratio and found no difference bilaterally. Tyler et al.[12] were able to establish a hip adduction: abduction ratio to predict if a hockey player is at risk for an adductor injury. Hockey players with adductor strength less than 80% of abductor strength were found to be 17 times more likely to experience an adductor strain during the season.[12] Previous research has primarily explored adductor injuries in males, examining dominant leg versus non-dominant leg and adductor: abductor strength comparisons.[12,23,24,25,26]

In female athletes, hip abduction and adduction strength research has focused primarily on those who have patellofemoral pain and emphasized the strength of the abductors alone.[27–29] In female athletes with patellofemoral pain, the hip abductors are significantly weaker when compared to the uninjured side and no difference in hip adductor strength has been found.[29] Evaluations of hip adduction strength in female soccer players, and comparing adductor strength in females to male soccer players remains absent. Normal values for hip adduction: abduction ratios have not been established for female athletes.

It is often assumed that male athletes exert a dominance in strength compared to their female counterparts. Female athletes have been found to have weaker quadriceps and hamstrings compared to males[30] and a decreased hamstrings: quadriceps ratio.[31] To our knowledge, strength differences in the hip adduction: abduction ratio between male and female soccer players has not been previously evaluated. When hip adduction and hip abduction peak torques are compared in males and females of the general population, males are found to have greater hip abductor peak torques compared to females, but no differences were found in hip adduction strength.[32]

Sugimoto et al.[33] investigated hip peak torques in male and female athletes (volleyball, basketball, baseball, and tennis) and found no difference in hip adduction strength; however, males showed significantly greater hip abductor peak torque values. Therefore, the aim of the current study was to evaluate hip adduction: abduction strength ratio between division 1 male and female soccer players. This study attempted to bridge the gap in the literature for understanding the ratio differences between male and female soccer players. It was hypothesized that males would a higher ratio than females.

Chapter 2: Literature Review

Muscles play an important role in adjusting the body to the necessary movements required from the body itself or the environment.[34] Muscle strength has been defined as the capacity of a muscle to produce the tension necessary for the maintenance of posture, initiation of movement or control of movement during a condition of loading on the musculoskeletal system.[34] Muscle strength can be used to assess the relationship between strength and the maintenance of health status.[34] The mechanism of injury to the adductor muscle is said to be a strength imbalance between the propulsive muscles and stabilizing muscles.[12] Factors theorized to contribute to groin injuries include muscle tightness, strength or flexibility asymmetry, insufficient strength of the prime muscles group, fatigue, incorrect technique, playing conditions, training errors, inadequate warm-up, and early return to play following an injury.[21]

Research conducted between male and female athletes has shown that males have stronger quadriceps and hamstrings than females.[35] In a study by Sugimoto et al.[33] hip adduction and abduction strength and hip abductor: adductor peak torques ratios in male and female athletes (volleyball, basketball, baseball, and tennis) were compared. Males demonstrated significantly greater hip abductor peak torques compared to females (males 1.29 ± 0.24 Nm/kg, females 1.13 ± 0.20 Nm/kg; $p = 0.03$). No difference in concentric adduction peak torques and hip abductor: adductor ratio was found. Tyler et al.[12] found a significant difference in hip adduction: abduction ratios between uninjured and those who sustained an adductor strain ($p = 0.038$). In those who suffered an adductor strain, their preseason hip adduction: abduction ratio was lower on the limb that sustained an injury compared to the uninjured group ($p = 0.011$). In regards to female athletes, the focus has been on athletes with patellofemoral pain. These studies have found weaker hip abductors in those with patellofemoral pain and no difference in hip

adduction.[27,29,28] From what previous literature has found, this current study will attempt to identify hip adduction: abduction strength ratios in male and female soccer players. This literature review attempts to understand the previous research performed on male and female athletes examining hip adduction and hip abduction strength and adduction: abduction ratio.

Hip Adduction and Abduction Strength

Adduction and Abduction Strength in Male Athletes

The hip adduction: abduction ratio has been studied in the male athlete population using isokinetic testing (Biodex or Cybex machine) or isometric testing (hand-held dynamometer). Research has examined the ratio to compare male athletes with previous or current adductor injuries and those who are pain-free or with no previous history of an adductor injury. The ratio has also been used to compare dominant and non-dominant legs with and without previous adductor injury.

Thorborg et al.[25] was the first to evaluate hip adduction and abduction strength profiles in male elite soccer players. Isometric hip adduction and abduction was tested on 100 soccer players with only 86 being included for the statistical analysis. The dominant limb was stronger than the non-dominant side for hip adduction (2.45 ± 0.54, 2.37 ± 0.48 Nm/kg, respectively, p = 0.02) and hip abduction (2.35 ± 0.33, 2.25 ± 0.31 Nm/kg, respectively, p<0.001). There was no difference in hip adduction: abduction ratio between the dominant (1.04 ± 0.18) and non-dominant limbs (1.06 ± 0.17, p=0.40). Another article by Thorborg et al.[24] examined hip adduction: abduction ratios in male soccer players with adductor-related groin pain. There was no significant difference between those with adductor-related groin pain and the control group (pain-free) (0.92 ± 0.23, 0.99 ± 0.18, p=0.353). There was also a 3% to 4% strength difference

in the dominant and non-dominant for both isometric hip adduction (2.45 ± 0.54 vs 2.37 ± 0.48 Nm/kg, p=0.02) and hip abduction (2.33 ± 0.33 vs 2.25 ± 0.31 Nm/kg, p<.001).

To understand the similarities in male soccer players and ice hockey players, Wilcox et al.[26] compared the strength of the hip for dominant and non-dominant legs in male ice hockey and soccer athletes. Ice hockey athletes had greater hip adduction on their dominant leg and greater range motion than the dominant leg of soccer players (both *p*=0.02). Ice hockey athletes had less adduction strength in their non-dominant leg than their dominant leg (*p*=0.02) as well as less strength in adduction than soccer athletes in their non-dominant leg (*p*=0.40). Soccer players had greater adduction strength in their dominant leg than non-dominant leg (*p*=.03). Ice hockey players had less hip adduction strength than soccer players. Mean hip abduction strength for ice hockey players was 2.26 ± 0.21 Nm/kg for dominant leg and 2.27 ± 0.23 Nm/kg for non-dominant leg, and mean hip adduction strength was 2.64 ± 0.28 Nm/kg in dominant leg and 2.39±0.25 Nm/kg for non-dominant leg. Mean hip abduction strength for soccer players was 2.45±0.31Nm/kg for dominant leg and 2.35±0.28 Nm/kg for non-dominant leg and mean hip adduction strength was 2.90 ± 0.33 Nm/kg for the dominant leg and 2.68 ± 0.36 Nm/kg for the non-dominant leg.

Preseason hip strength testing can identify ice hockey players that are at higher risk of developing an adductor strain.[12] Tyler et al.[12] found an 18% hip adduction strength deficit during preseason in eight players who sustained a groin injury during the season (*p*=0.02) compared to those who were uninjured. A total of 47 players were used for data collection over the course of two seasons, with 8 players sustaining a total of 11 adductor strains. Within the 47 players used for data collection, 141 general injuries occurred which gave a rate of 17 injuries per 1000 player-exposures, specifically there was an incidence of 3.2 adductor strains per 1000

player exposures. In those who sustained a groin injury, there was no difference in adductor strength between the injured and the uninjured limb (*p*=0.18). The hip adduction: abduction ratio was significantly different between the injured group and control group (uninjured) (*p*=0.038). Preseason hip adduction: abduction strength ratio was lower on the injured limb compared to the uninjured limb (*p*=0.011). In this study, Tyler et al[12] was able to establish a ratio that could predict if an athlete is at risk for an adductor injury; the risk for injury is 17:1 if hip adduction is less than 80% of abduction. To our knowledge, this is the only study that has established a standard ratio for a sport.

In regard to the rate of injury for soccer players, Engebretsen et al.[22] examined 508 players in the Norwegian first, second and third division of men's soccer to seek potential intrinsic risk factors for overuse and groin strain injuries. Each player completed a clinical examination and a questionnaire, an isometric adductor strength test with a hand-held dynamometer, three counter-movement jumps, and two 40-m sprint tests. A total of 61 groin injuries were reported, affecting 55 legs and 51 (10.0%) players. A total of 31 to the right leg and 30 on the left of which 22 were acute and 39 were overuse groin injuries. With a total of playing and training hours of 108,111, the overall incidence of injuries during the season was 4.7 injuries per 1000 playing hours (95% confidence interval [CI], 4.3-5.1), 12.1 (95% CI, 10.5-13.7) for match injuries, and 2.7 (95% CI, 2.4-3.1) for training injuries. Specifically, for groin injuries, the total incidence of groin injuries was 0.6 injuries per 1000 playing hours (95% CI, 0.4-0.7), 0.3 injuries per 1000 training hours (95% CI, 0.2-0.4), and 1.8 injuries per 1000 match hours (95% CI, 1.2-2.5). The multivariate analysis showed that previous acute groin injury (adjusted odds ratio [OR], 2.60; 95% CI, 1.10-6.11) and weak adductor muscles determined

clinically (adjusted OR, 4.28; 95% CI, 1.31-14.0) were significant predictors of increased risk of groin injuries.

Belhaji et al.[36] reported isokinetic measures of the hip abductor and adductor muscle groups in male soccer players who suffer from chronic adductor related groin pain (ARGP) comparing them to those soccer players who are uninjured and volunteers from a healthy population. The Cybex Norm Isokinetic Dynamometer System was used to assess isokinetic torques at 60°/s and 120°/s. The total number of subjects was 21 male soccer players and ten healthy volunteers; 9 soccer players with chronic ARGP, and 12 asymptomatic (non-ARGP) soccer players. Results indicated that the abductor muscle group was significantly stronger than the adductor muscle group and peak torques for the chronic ARGP group and non-ARGP group were statistically different in strength on the dominant (p=.0001) and non-dominant sides (p=0.002) (players with ARGP abductor muscle peak torque: 147.22 ± 29.55 N/m for affected and 142.78 ± 26.19 N/m; players with ARGP adductor muscle peak torque: 69.56 ± 36.32 N/m for affected and 101.56 ± 35.42 N/m for unaffected). Hip abduction strength for players with ARGP was 145.00 ± 29.55 N/m for dominant and 145.00 ± 26.39 N/m for non-dominant, asymptomatic players dominant leg 129.17 ± 22.87 N/m and non-dominant leg 131.83 ± 19.14 N/m, and volunteer dominant leg 79.50 N/m and non-dominant leg 79.30 ± 20.85 N/m. Hip adduction strength for players with ARGP was 71.78 ± 37.10 N/m for dominant and 99.33 ± 36.69 N/m for non-dominant leg, asymptomatic player's strength for dominant leg was 111.25 ± 23.97 N/m and 115.50 ± 36.77 N/m for non-dominant leg, and strength for volunteers was 101.50 ± 16.89 N/m for dominant leg and 102.90 ± 15.74 N/m for non-dominant. There was no difference between soccer players and healthy volunteers in the abductor: adductor torque ratios between dominant and non-dominant limb. Finally, between soccer players in the adductor-

related groin pain and non-adductor-related groin pain, significant difference was found in strength in both the dominant and non-dominant sides (p=0.00 and p=0.00, respectively).

Overall, previous research indicates that in ice hockey players, indicators for a groin injury include preseason strength, previous groin injury and weak adductor muscles.[22] In soccer players, Thorborg et al.[24] was the first to evaluate isometric strength of hip adduction and hip abduction of soccer players and found a 3% strength difference between the dominant leg and the non-dominant leg. In athletes who have had a previous groin strain, weaker adductor muscles and a previous medical history of groin strains were identified risk factors for a future groin injury.[36,22,25,12] A low hip adduction: abduction ratio can also be an indicator for an adductor strain in ice hockey players[12], however, there is no other research that has examined hip adduction: abduction ratio as an indicator for other sports. In summary, strength differences in hip adduction and abduction in male athletes have been found to put an athlete at risk for injury[19,20] and clinically is just as important to understand these strength measures and ratios in female athletes.

Hip Adduction and Abduction in Female Athletes

Young active females are shown to have weaker hip abductors which could be linked to patellofemoral pain.[29] Cichanowski et al.[29] tested Division III collegiate female athletes from four difference colleges and tested six hip muscle groups in athletes diagnosed with unilateral patellofemoral pain compared to the unaffected legs and with non-injured sports-matched controls. The six muscle groups tested were hip flexors/extension, hip abductors/adductors and hip internal/external rotators. Hip peak torques were normalized to body mass. For the purpose of this literature review, we will only focus on the hip abductor/adductors. The mean force produced by the injured abductor muscle group was significantly weaker than the mean force

produced by the noninjured leg (*p*=0.003) (injured peak torque abduction: 0.290 ± 0.08, non-injured: 0.330 ± 0.07, *p*=0.003; injured peak torque adduction: 0.198 ± 0.07, non-injured: 0.195 ± 0.05, *p* =0.65). No difference was found in hip adductor mean force.

Cichanowski et al.[29] concluded that hip abductor weakness is associated with patellofemoral pain in female collegiate athletes. Bolgla et al.[27] and Ireland et al.[28] saw the same results in a female general population with patellofemoral pain and found a 26% less hip abduction strength (*p*<.001) compared to those without patellofemoral pain.

Isokinetic Testing

Isokinetic testing has been a reliable source of strength testing in athletes.[37] Isometric testing has been established to be more valid and reliable method however, isokinetic testing gives an enhanced representation of dynamic muscle action.[38] Isokinetic testing allows for joint movements to be performed for concentric or eccentric muscle strength at fixed angular velocities.[37] The recorded measure for the lower leg is the net force effect of the force developed by the quadriceps and hamstrings to move the knee joint into flexion and extension.[37] The knee joint has been the main focus of isokinetic testing and has been validated. Hip joint torques tested using the Biodex Dynamometer have been validated.[38]

An article published by Meyer et al.[38] tested the validity of the Biodex isokinetic dynamometer to test hip abduction/hip adduction and hip flexion/extension. For the purpose of this literature review, the focus will be on hip abduction/adduction. A total of 18 volunteers (10 men and 8 women) for the study. Two identical tests were performed at the same time of day one week apart to investigate test-retest reliability. A 10-minute warm up on a cycle ergometer was performed before assessing maximal isokinetic and isometric peak torques. For hip abduction/adduction testing, participants were side-lying on the chair facing the dynamometer.

The testing leg was locked into a brace to ensure full knee extension and was strapped to the dynamometer pad at the femur level to try to eliminate hip rotation. The first position for the hip joint was set at 0^{o} of flexion and full adduction during isokinetic testing. The non-tested hip and knee were flexed (45^{o} and 60^{o}, respectively) for ease and steadiness then strapped to the dynamometer chair. The outcome parameters were peak torque (PT), normalized peak torque (PT_{norm}) and the maximum value for each set of repetitions were used for statistical analysis. Mean and standard deviations were calculated for maximum PT and PT_{norm}. The tables below, from the article, show the reliability, variability and clinical important changes using the Biodex dynamometer.

Figure 1. Hip torques measurement results from Meyer et al.[38]

Table 1. Reliability, variability and clinical important change of hip torque measures using Biodex dynamometer.

Test condition	Hip tests	Mean (95% CI)		ICC (95%CI)		SEM	SEM (%)	SRD_{95}	SRD_{95} (%)	CV_b (%)
Isometric	**Abduction**	**117.40**	**101.53-133.40**	**0.91**	**0.77-0.96**	**10.12**	**8.62**	**28.06**	**23.89**	**27.11**
	Flexion	103.79	85.83-121.75	0.97	0.93-0.99	4.47	4.31	12.40	11.94	34.10
	Extension	161.10	142.50-179.70	0.77	0.43-0.91	15.88	9.86	44.02	27.32	19.97
Isokinetic	Abduction	120.23	104.47-136.00	0.83	0.60-0.93	13.09	10.89	36.28	30.17	25.62
60°/s	Adduction	91.55	74.11-108.99	0.68	0.33-0.87	15.61	17.05	43.28	47.27	35.34
	Flexion	122.66	104.28-141.04	0.92	0.80-0.97	10.51	8.57	29.13	23.75	30.06
	Extension	130.50	107.97-153.03	0.84	0.61-0.93	12.66	9.70	35.10	26.90	33.73
Isokinetic	Abduction	106.24	90.71-121.78	0.89	0.74-0.96	10.53	9.91	29.19	27.48	29.12
120°/s	Adduction	85.15	70.76-99.54	0.76	0.46-0.90	12.02	14.12	33.32	39.13	32.24
	Flexion	105.18	89.28-121.08	0.93	0.82-0.97	8.41	8.00	23.32	22.17	30.39
	Extension	123.30	101.92-144.68	0.80	0.55-0.92	16.11	13.06	44.65	36.21	33.58

doi: 10.1371/journal.pone.0081149.t001

Figure 2. Normalized hip torque measurements from Meyer et al.[38]

Table 2. Reliability, variability and clinical important change of normalized hip torque measures using Biodex dynamometer.

Test condition	Hip tests	Mean (95% CI)		ICC (95%CI)		SEM	SEM (%)	SRD_{95}	SRD_{95} (%)	CV_b (%)
Isometric	**Abduction**	**7.71**	**5.68-9.75**	**0.96**	**0.91-0.99**	**0.80**	**10.41**	**2.23**	**28.86**	**53.66**
	Flexion	6.17	4.57-7.77	0.98	0.95-0.99	0.37	6.04	1.04	16.79	49.12
	Extension	11.54	7.80-15.28	0.98	0.95-0.99	0.96	8.28	2.65	22.95	59.65
Isokinetic	Abduction	8.00	5.85-10.15	0.97	0.91-0.99	0.76	9.48	2.10	26.26	54.65
60°/s	Adduction	5.81	4.13-7.50	0.79	0.52-0.91	1.38	23.79	3.83	65.96	55.85
	Flexion	7.87	5.88-9.86	0.99	0.96-0.99	0.48	6.09	1.33	16.89	51.62
	Extension	8.8	5.97-11.63	0.93	0.81-0.97	1.18	13.37	3.26	37.07	64.54
Isokinetic	Abduction	7.00	5.13-8.87	0.96	0.90-0.99	0.76	10.85	2.11	30.07	54.23
120°/s	Adduction	5.58	3.94-7.23	0.93	0.83-0.97	0.74	13.28	2.05	36.81	59.24
	Flexion	6.75	5-8.49	0.98	0.95-0.99	0.47	7.00	1.31	19.41	52.76
	Extension	8.16	5.76-10.55	0.96	0.91-0.99	0.88	10.74	2.43	29.77	62.97

Abbreviations: CI, confidence intervals; Nm, Newton meter; Nm/kg, newton meter per kilogram; s, second; ICC, intraclass correlation coefficient; SEM, standard error of measurement; SRD_{95}, smallest real difference at 95% confidence interval; CV_b, between subject variability.

doi: 10.1371/journal.pone.0081149.t002

The Biodex has been validated for knee flexion and extension and hip abduction and adduction in this study done by Meyer et al.[38] The Biodex can produce highly statistical significant reliability measurements for muscular performance.[39] Specifically for this current study, the validity of using the Biodex for hip adduction and abduction will allow for accurate strength findings to be used.[39,38]

Conclusion

Hip adduction and abduction has been primarily researched in male athletes. The primary outcomes from previous research was to compare uninjured athletes to those with current or previous groin strains and comparing the dominant to non-dominant leg. Results show that the injured leg, primarily the dominant leg, has weaker adductor strength than the non-dominant leg or uninjured group. [36,22,40,21,23,25,12] Research in hip adduction and abduction strength has surrounded healthy male and female athletes with limited research on strength of females. Specifically, for the current study, the sport of soccer has limited research to show significant differences between female and male players.

Chapter 3: Methods

Purpose:

The purpose of the current study was to determine if there was a significant difference in hip adduction: abduction strength ratio measures between division 1 male and female soccer players.

Participants:

Nineteen NCAA Division 1 male and female soccer players were recruited for the study (11 female, 8 male). A Human Subjects Committee approved informed consent form was given to each subject for signature, following explanation of the study and opportunity for questions. Additionally, a medical history survey was given to evaluate if subjects met the inclusion criteria. Inclusion criteria included participating in one full season of Division 1 soccer, having been cleared for full participation by a physician or athletic trainer from a previous injury and willingness to consent for participation. Exclusion criteria included lower extremity injury within the last two months preventing participation and/or lower extremity surgery within the past year. For the purpose of the current study, injury is defined as any physical complaint sustained by a player that resulted from a soccer match or soccer training, forcing the player to miss or be unable to take full part in future soccer training or match play.[22] Following screening of the medical history survey for inclusion and exclusion criteria, it was found that only nine females and five males were eligible to continue study participation.

Procedure:

Instrumentation

Data collection was carried out on using a Biodex-dynamometer (Biodex Medical Systems, Shirley, NY) to measure isokinetic strength of hip adduction and abduction in concentric mode.[36]

Positioning of the Subjects

The dominant leg was tested first and was identified as the leg the subject uses to kick a ball.[23,25] Subjects were positioned on the Biodex in a side-lying position for the hip abduction-adduction measurements (Figure 1).[36,31] The testing leg was secured just above the knee into the hip pad with the axis of rotation being superior and medial to the greater trochanter.[36] Gravity correction was incorporated by having the limb of the subject weighed prior to isokinetic testing.[36] The leg was weighed by the subject raising the leg slightly, holding the leg in that position, and the subject relaxing the leg completely while the dynamometer measured the limb weight. This gravity correction eliminates the error of weight that could be caused by the dynamometer attachment and weight of the body segment.[41]

Figure 3. Position of subject

Testing Protocol

Concentric isokinetic hip abduction and hip adduction were collected. The dynamometer was calibrated to ensure reliable measurements as well as using the stabilizing straps to prevent unwanted movement.[42] The subjects performed three familiarization repetitions at 60^{o}/s to become accustomed to the speed and movement required for data collection. The protocol consisted of one set of five continuous repetitions at 60^{o}/s. The dominant side was collected first followed by the non-dominant side.[36] Subjects were encouraged to push and pull as hard as they could against the resistance to exert maximal efforts.[36] All tests were conducted by the same member of the research team and followed the same protocol.

Data and Statistical Analysis:

Descriptive statistics were calculated for age, height, and body mass. Independent t-tests were used to compare absolute data for hip adduction and abduction peak torques, and adduction: abduction ratio between male and female soccer players for the dominant and non-dominant limb. Pearson's correlation was used to determine if there was a correlation between absolute hip peak torque strength and body mass. Significance was accepted at $p<0.05$ for independent t-tests and Pearson's correlation.

Next, hip adduction and abduction peak torques were normalized to body mass by the following way: 1) peak torques for adduction and abduction of the dominant and non-dominant leg were converted from foot-pounds(ft-lb) to newton meters (Nm) by multiplying the peak torques*1.355818. 2) To normalize the data to body mass, the peak torques for adduction and abduction were divided by body mass (peak torque(Nm)/Body mass(kg)). 3) Finally, the ratio was calculated by dividing adduction (Nm/kg) by abduction (Nm/kg). Independent t-tests (significance at $p<0.05$) were used to compare normalized data for hip adduction and abduction

peak torques. Pearson’s correlation (significance at $p<0.05$) was used again for normalized strength and body mass.

Chapter 4: Results

Descriptive statistics were calculated for age, height and body mass for both sexes (Table 1). Male and female groups were significantly different in height ($p=0.02$) and body mass ($p<0.01$).

Table 1. Subject demographics (mean ± SD)

	Females n=9	Males n=5	*p*
Height (m)	1.64 ± 0.65	1.76 ± 0.09	0.02*
Body Mass (kg)	60.08 ± 5.94	80.72 ± 4.72	<0.01*
Age	20.11 ± 1.17	20.20 ± 1.64	0.91
Right Leg Dominant	7	5	
Left Leg Dominant	2	0	

* Significant difference between genders

Independent t-tests were used to calculate significance between hip adduction and abduction peak torques and adduction: abduction ratios (Table 2 and Table 3, respectfully). Males had significantly greater absolute hip abduction torque in the dominant ($p<0.001$) and non-dominant ($p=0.01$) limb compared to females. Absolute hip adduction torque was not significantly different between genders (dominant, $p=0.08$; non-dominant, $p=0.33$). Additionally, absolute hip adduction: abduction ratios were not significantly different between genders in the dominant ($p=0.52$) and non-dominant ($p=0.59$) leg.

Table 2. Hip adduction and abduction peak torques for absolute data (mean ± SD)

	Females	Males	*p*
Hip abduction dominant	69.2 ± 10.40 ft-lb	105.06 ± 17.94 ft-lb	<0.001*
Hip abduction non-dominant	72.57 ± 14.30 ft-lb	102.16 ± 18. 68 ft-lb	0.01*
Hip adduction dominant	26.99 ± 6.71 ft-lb	45.74 ± 17.62 ft-lb	0.08
Hip adduction non-dominant	35.58 ± 11.81 ft-lb	43.54 ± 17.75 ft-lb	0.33

* Significance p<0.05

Table 3: Hip adduction: abduction ratios (mean ± SD)

	Female	Male	*p*
Hip adduction: abduction ratio dominant	38.88% ± 6.63%	46.87% ± 25.37%	0.52
Hip adduction: abduction ratio non-dominant	48.46% ± 10.75%	43.85% ± 21.14%	0.59

Pearson's correlation was used to determine if there was a correlation between body mass and strength measures. A positive correlation was found in absolute hip abduction strength and body mass for the population as a whole (abduction dominant: $r=0.769$, $p<0.001$; abduction non-dominant: $r=0.713$, $p=0.004$) (Table 4). Due to a significant positive correlation, hip abduction and adduction peak torques were scaled to body mass and are shown in Table 5. There was no significant difference in hip abduction for dominant ($p=0.28$) and non-dominant ($p=0.77$) between genders when scaled to body mass. Hip adduction peak torques scaled to body mass for dominant ($p=0.37$) and non-dominant ($p=0.66$) was not significantly different between genders. There was not a significant correlation between body mass and hip strength scaled to body mass (Table 6).

Table 4. Correlations between body mass and absolute hip strength

	Abduction Dominant	Abduction Non-dominant	Adduction Dominant	Adduction Non-dominant
Mass:	0.769* p<0.001	0.713* p=0.004	0.374 p=0.19	0.093 p=0.75

*Significance p<0.05

Table 5. Hip abduction and adduction peak torques scaled to body mass (mean ± SD)

	Females	Males	*p*
Hip abduction dominant	1.16 ± 0.23 Nm/kg	1.30 ± 0.16 Nm/kg	0.28
Hip abduction non-dominant	1.22 ± 0.27 Nm/kg	1.26 ± 0.17 Nm/kg	0.77
Hip adduction dominant	0.46 ± 0.13 Nm/kg	0.58 ± 0.25 Nm/kg	0.37
Hip adduction non-dominant	0.60 ± 0.22 Nm/kg	0.54 ± 0.24 Nm/kg	0.66

Table 6. Correlations between body mass and hip strength scaled to body mass

	Abduction Dominant	Abduction Non-dominant	Adduction Dominant	Adduction Non-dominant
Mass:	0.115 p=0.70	-0.014 p=0.96	-0.011 p=0.97	-0.357 p=0.21

Chapter 5: Discussion

The primary purpose of this study was to determine if there was a significant difference in hip adduction: abduction ratios between male and female soccer players. We hypothesized that males would have a higher hip adduction: abduction ratio than females. However, no significant difference was found between genders. Therefore, the null hypothesis was accepted.

The current study examined absolute hip adduction and abduction peak torques, and hip adduction and abduction peak torques scaled to body mass. A significant difference was found in the dominant and non-dominant absolute hip abduction peak torques. Males produced a significantly greater hip abduction peak torques in dominant (105.06 ± 17.94 ft-lb) and non-dominant (102.16 ± 18. 68 ft-lb) limbs than females (dominant, 69.2 ± 10.40 ft-lb; non-dominant, 72.57 ± 14.30 ft-lb) for both dominant ($p<0.001$) and non-dominant ($p=0.01$) limbs. Pearson's correlation was used to determine if there was a relationship between body mass and strength measures. A positive correlation was seen between body mass and absolute hip abduction. From these findings, the data was normalized to body mass to eliminate the effect of mass and evaluate if there was still a correlation. Body mass has been shown to have an effect on hip adduction and abduction peak torque.[43] Normalized hip adduction peak torque for dominant (female: 0.46 ± 0.13 Nm/kg, male: 0.58 ± 0.25 Nm/kg, $p=0.37$) and non-dominant (female: 0.60 ± 0.22 Nm/kg, male: 0.54 ± 0.24 Nm/kg, $p=0.66$) limbs were not significantly different. Normalized hip abduction for dominant (female: 1.16 ± 0.23 Nm/kg, male: 1.30 ± 0.16 Nm/kg, $p=0.28$) and nondominant (female: 1.22 ± 0.27 Nm/kg, male: 1.26 ± 0.17 Nm/kg, $p=0.77$) were not significantly different.

Our findings for hip abduction differed from that of Sugimoto et al.[33] who found a significant difference in hip abduction between genders possibly due to the sports involved or the

small sample size of the current study. Sugimoto et al.[33] found a significant difference (p=0.03) in normalized hip abduction peak torque between male (1.29 ± 0.24 Nm/kg) and female (1.13 ± 0.20 Nm/kg) and no significant difference in hip adduction peak torques (male: 0.75 ± 0.32 Nm/kg, female: 0.72 ± 0.27, p=0.79 Nm/kg). Table 7 displays the results of the current study and Sugimoto et al.[33] for better comparison. Sugimoto et al.[33] theorized that females have a wider pelvis than males causing a decrease in hip abductor peak torques potentially leading to greater kinematic alteration in females. Jacobs et al.[44] theorized that the greater pelvic width increases the lever arm on the hip abductors and this can reduce the force production of the hip abductors.

Table 7. Comparison of normalized hip peak torques

		Current Study (Nm/kg)	Sugimoto et al.[33] (Nm/kg)
Females	Dominant abduction	1.16 ± 0.23	1.13 ± 0.20
	Non-dominant abduction	1.22 ± 0.27	
	Dominant Adduction	0.46 ± 0.13	0.72 ± 0.27
	Non-dominant adduction	0.60 ± 0.22	
Males	Dominant abduction	1.30 ± 0.16	1.29 ± 0.24
	Non-dominant abduction	1.26 ± 0.17	
	Dominant Adduction	0.58 ± 0.25	0.75 ± 0.32
	Non-dominant adduction	0.54 ± 0.24	

Adduction: abduction ratios have not been extensively researched. Results of the current study for hip adduction: abduction ratios scaled to body mass were not significantly different between genders (female dominant: 0.41 ± 0.09, male dominant: 0.47 ± 0.25, p=0.25; female non-dominant: 0.48 ± 0.11, male non-dominant: 0.43 ± 0.21, p=0.30). These findings support the

conclusions of Sugimoto et al.,[33] who hypothesized that gender differences in abduction: adduction peak torque ratios would be observed and found no significant difference as well (males: 0.64 ± 0.21, females: 0.57 ± 0.18, p=0.32). This current study and Sugimoto et al.[33] conclude that gender does not play a role in hip adduction: abduction ratios. To further investigate if body mass influences hip abductor and adductor strength within the population as a whole, a Pearson's correlations was conducted. A significant positive correlation was found between body mass and absolute hip abduction strength, in both dominant and non-dominant limbs (r=.769, p=0.001; r=0.713, p=0.004, respectively) and no significant correlation was found in hip adduction strength, in both dominant (r=0.374, p=0.19) and non-dominant (r=0.093, p=0.75). This positive correlation was hypothesized to be due to the abductors' use in stabilizing the hip during gait. As body mass increases, the strength of the abductors must also increase corresponding to the increased magnitude of the center of mass that must be stabilized during single leg stance. However, when hip abductor strength was scaled to body mass, the correlation between strength and body mass was eliminated. These findings can be supported by Bazett-Jones et al.[43], who investigated the most effective way to compute body-size-independent hip strength measures using muscle-specific allometric scaling and ratio standard normalization scaling. For the purpose of this discussion, only hip abduction results will be reviewed. Bazett-Jones et al.[43] found that nonnormalized hip abduction torque was significantly correlated with body mass (r=0.606, p<0.001). The findings in Bazett-Jones et al.[43] study supported normalizing the data for the current study to eliminate the effect of body mass because there was significant correlation in absolute hip abduction peak torques in the dominant and non-dominant leg. The findings from Bazett-Jones et al. theorize that the need for normalization of data to reduce the influence of body mass on strength.[43]

The current study was drawn by the framework of the research surrounding the hamstring: quadriceps ratio. A normal hamstrings: quadriceps ratio is between 50 and 80%; the closer to 100%, the more functional capacity of the hamstrings to provide stability of the knee.[45] The hamstring: quadriceps ratio measures isokinetic eccentric peak torque of the hamstrings relative to the isokinetic concentric peak torque of the quadriceps during leg extension.[34] This ratio has been used to examine moment-velocity patterns between hamstrings and quadriceps and to asses knee functional ability and musculature balance.[45] It is also known that females have a lower hamstring: quadriceps ratio than males.[31] The hamstrings: quadriceps ratio has allowed physicians to determine if athletes can return to play following an anterior cruciate ligament rupture and to identify if any imbalances between these muscles still exist.[31] Since the hamstrings: quadriceps ratio is established and helps in the rehabilitation setting, examining the hip adduction: abduction ratio could potentially do the same with adductor strains.

Unlike the hamstring: quadriceps ratio, there has not been an established normalized adductor: abductor ratio to indicate if a soccer player is at risk for injury.[46] Tyler et al.[47] established hip adduction: abduction ratio in male hockey players. The results showed an athlete has a 17:1 chance of an adductor strain if hip adduction was less than 80% of abduction strength.[47] Since soccer player's actions are predominantly open chain (kicking a ball), this ratio found in hockey players may not be comparable to closed chain movements.[46] Thorborg et al.[24] was the first to attempt to establish a normalized ratio for elite soccer players in athletes recovering from a groin injury, but the measurement tool, a hand-held dynamometer was found to be unreliable.[46] Thorborg et al.[24] suggested that a hip adduction: abduction ratio of more than 90% and equal bilateral strength in athletes recovering after a groin injury. Griffin, Everett, and Horsley[46] suggested that the dominant leg ratio should be 1.45-1.6 and 1.25-1.45 on the non-

dominant side.[46] In our study, dominant leg ratio for males ranged from 0.23-0.74 and non-dominant leg ratios ranged 0.26-0.79. All male participants are below the ratio suggested by Griffin, Everett and Horsley[46], potentially putting the male participants at risk for an injury to their dominant and non-dominant leg. Also, the authors recommended the adductors on the dominant limb should be 18%-22% stronger than the non-dominant limb.[46] In our study, one male subject had equal strength of the adductors, two subjects had stronger hip adductors on the non-dominant limb, one subject was 68% stronger than their non-dominant limb and another was 77% stronger than their non-dominant limb. Further research should investigate if soccer players below the ratio suggested by Griffin, Everett and Horsley have developed a musculoskeletal injury to the adductor musculature. Research has focused on examining hip adduction and abduction peak torques in male and female's, more so in the male athlete population, as it relates to injuries and little research to establish a normal strength ratio for hip adduction: abduction.

Limitations of the study include the timing of testing (during off-season training), the time of day, activity that has already been completed prior to testing, and the potential for athletes to not report injuries to be able to participate in competition. During off season training, training is less rigorous soccer-specific and more strength and conditioning sessions compared to the fall season, which has an increased volume of regular season play. Players participated in this study following either weight training or soccer practice. This could cause the athlete to produce less torque and not produce maximum effort. A total of 19 players volunteered to participate in the study, however, three males and two females were excluded due to injuries in the previous two months that prevented them from participating in practice or competition.

From this study, it can be concluded that there is no difference in hip adduction: abduction ratios between division 1 male and female soccer players. Establishing a normalized

ratio can help athletic trainers and strength and conditioning coaches correct imbalances between hip adduction and abduction muscles. Although a groin injury rate has been confirmed with male athletes, female athletes have not been examined for groin injury rates. Further research should investigate this to determine if groin injuries occur at the same rate as males.

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Curriculum Vitae

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