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ORIGINAL RESEARCH

THE INFLUENCE OF HIP JOINT ANGLE ON THE RATIO BETWEEN ADDUCTION AND ABDUCTION TORQUE IN EXPERIENCED, RECREATIONAL MALE ICE HOCKEY PLAYERS

Patrick Welsh, DC, FRCCSS(C)[1]
Scott Howitt, DC, FRCCSS(C)[1]
Samuel J. Howarth, PhD[1]

ABSTRACT

Background: Strains of the adductor muscle group of the hip are common amongst ice hockey players. The ratio of isometric strengths between the hip adductors and abductors has been offered as a risk factor for hip adductor strain; however, there is no description for how the ratio between hip adductor and abductor strength varies as a function of hip abduction angle.

Hypothesis/Purpose: The aim of this study was to determine the influence of hip joint abduction angle on measured ratios of hip adduction to abduction torque in experienced, recreational, male hockey players. The primary null hypothesis for this study was that hip joint abduction angle would not influence hip adduction-to-abduction torque ratios in male hockey players.

Study Design: Counterbalanced observational cohort.

Methods: Twelve uninjured, male, recreational hockey players, with a minimum experience level of midget AAA/minor competitive or equivalent. Participants performed maximal isometric side-lying hip adduction and abduction exertions against a rigidly constrained load cell at 0, 10, and 20 degrees of hip abduction. Measured peak torques from each exertion were used to derive the hip adductor-to-abductor torque ratio. Kinematics of the trunk, pelvis, and lower limbs were monitored using an optoelectronic motion capture system.

Results: Adductor-to-abductor torque ratio increased from 1.49 (SD = 0.20), to 1.92 (SD = 0.20) and to 2.30 (SD = 0.54) with successively increasing hip abduction angle ($p < 0.001$). Peak torque was significantly different between all angles ($p \leq 0.016$) except between adduction exertions performed at 10 and 20 degrees of abduction ($p = 0.895$). Small changes in hip angle during the exertion were coincident with exertion direction, which confirmed the isometric nature of the task.

Conclusion: Hip abduction angle has a significant impact on the measured adductor-to-abductor torque ratio. The ratio increased due to a combination of increased adductor torque and decreased abductor torque as the hip abduction angle increased.

Level of Evidence: 2b

Keywords: Athletes, isometric dynamometry, groin pain, hip injuries, hip strength

[1] Division of Research and Innovation, Canadian Memorial Chiropractic College, Toronto, ON, Canada

Conflict of interest: The authors have no conflicts of interest to declare.

CORRESPONDING AUTHOR
Dr. Samuel J. Howarth, PhD
Associate Professor
Director, Human Performance Research
McMorland Family Research Chair in Mechanobiology
Canadian Memorial Chiropractic College
Toronto, ON, Canada
M2H 3J1
T: +1-416-482-2340 x.236, F: +1-416-482-2560
E-mail: showarth@cmcc.ca

INTRODUCTION

Hip adductor strains are significant injuries at both the minor and professional levels of ice hockey, representing up to 10% of all injuries and 43% of all muscle strains.[1-3] Strength imbalances between agonist and antagonist muscle groups have been associated with a variety of sport-related injuries including muscle strains.[4-6] Of particular interest is the link drawn between agonist and antagonist strength imbalances and adductor strains in elite hockey players.[7] Specifically, the average adduction-to-abduction strength ratio (measured using a handheld dynamometer) of players that sustained an adductor strain was 0.78, and the average ratio for players who did not become injured was 0.95. Since the original study, several other researchers have reported hip strength[8-11] and torque ratios[12-14] for injured and uninjured elite athletes participating in a variety of sports and non-athletes with femoroacetabular impingement; however, protocol inconsistencies hinder the potential for comparing hip adductor-to-abductor strength/torque ratios across studies. Particular inconsistencies include participant positioning (e.g. supine-lying, side-lying), hip posture (e.g. abduction/adduction angle), participant compensations/restraints (e.g. using assessment table for support), and task (e.g. isometric, isokinetic).

Hip abduction posture is particularly important for isometric dynamometry in the frontal plane. Hip abductor muscle lengths decrease while the adductor muscle lengths increase as the hip is abducted.[15] Changes in hip abductor and adductor muscle length with increasing hip abduction angle are likely to impact the position on the force-length relationship at which the muscles operate. Previous work has demonstrated that peak hip abduction force/torque decreases and peak hip adduction force/torque increases with increasing hip abduction angle.[9,16] Hypothetically this means that the adduction-to-abduction torque ratio would also increase with increasing hip abduction angle; however, the impact of changing the hip abduction angle on the adduction-to-abduction torque ratio has not been directly investigated.

The primary goal of this investigation was to determine the influence of hip joint abduction angle on measured ratios of hip adduction to abduction torque in experienced, recreational, male hockey players. It was hypothesized that the ratio would increase with greater hip abduction angles. A secondary objective was to evaluate the accuracy of participant positioning and to monitor the effectiveness of restraints to preserve the isometric nature of the task.

METHODS

Participants

Male participants were recruited from local recreational ice hockey teams. Inclusion criteria stipulated that participants had to currently play recreational ice hockey (minimum once per week)[17] and have a minimum level of experience equivalent to or greater than midget AAA/minor competitive. Goaltenders were excluded from participating due to the difference in their functional demands compared to skaters. Additional exclusions were those with a current lower body injury or low back pain, an adductor strain within the prior year, neurological impairments, previous surgery in the lower limb or spine, current involvement in a concussion return-to-play protocol, diagnosed hip pathology, and uncontrolled diabetes. All participants provided written informed consent and the study protocol was approved by the Research Ethics Board at the Canadian Memorial Chiropractic College (REB #1504B01).

Instrumentation

Kinetic

Forces exerted during each task were measured by a uniaxial load cell (MLP-1K, Transducer Techniques, Temecula, CA, USA) that was fixed to a chain. Stated measurement error for the load cell was 0.05% of the full-scale (1000 pounds).[18] The chain was secured to the ceiling for adduction trials (Figure 1A) or to an immovable weight on the floor for abduction trials (Figure 1B). Analog data were digitally sampled at a rate of 1000 Hz using a $\pm$10V range on a 16-bit analog-to-digital conversion board (ODAU III, Northern Digital Inc., Waterloo, ON, Canada).

Kinematic

Three-dimensional kinematic data were recorded from the shank bilaterally, pelvis, and thorax with

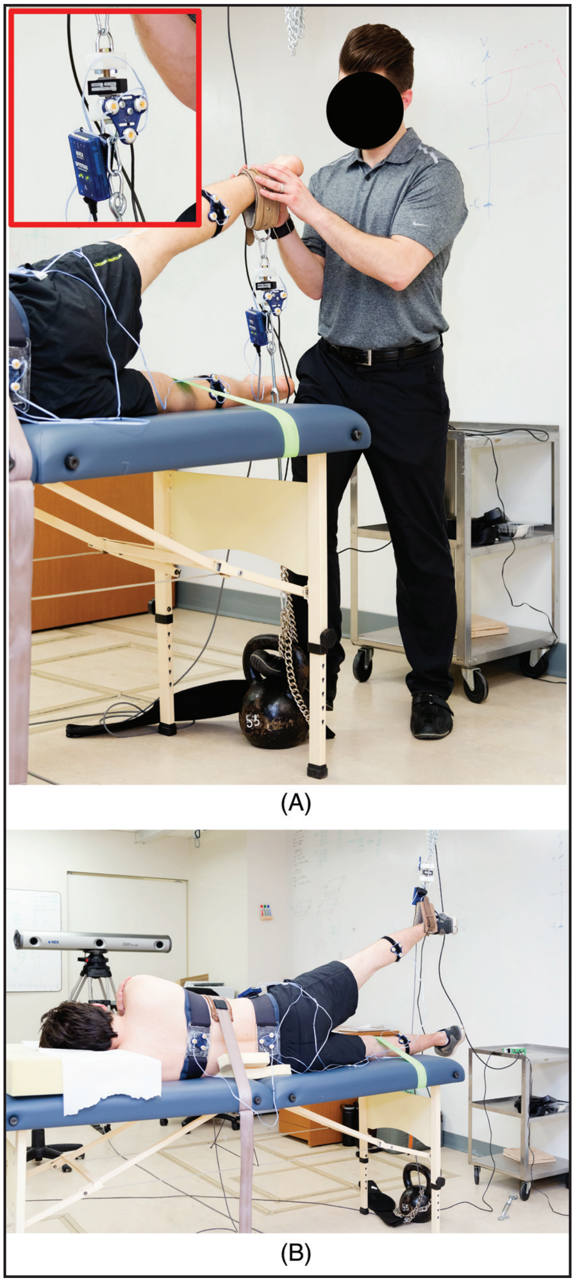

Figure 1. *Patient positioning for an abduction (A) and adduction (B) trial.*

two optoelectronic cameras (Optotrak Certus, Northern Digital Inc., Waterloo, ON, Canada). The Optotrak Certus cameras are capable of measuring the position of an infrared-light emitting diode (IRED) with an accuracy of 0.1 mm and resolution of 0.01 mm.[19] Separate rigid bodies holding three IREDs were strapped to each of the participant's shanks at the widest point of the gastrocnemius, to the pelvis at the level of the anterior superior iliac spines (ASISs), and around the thorax at the approximate level of the sixth thoracic vertebra (T6). A fifth rigid body was attached to the uniaxial load cell to continuously monitor its position and orientation. An investigator digitized additional anatomical landmarks while the participant stood in an upright and anatomically neutral posture. Specific bilateral landmarks were the ASISs, iliac crests, greater trochanters, medial and lateral aspects of the knee joints, tibial tuberosities, medial and lateral malleoli, and acromion processes. Unilateral landmarks were the suprasternal notch, xiphoid process, and the spinous processes of the twelfth thoracic (T12) and fifth lumbar (L5) vertebrae. Two marked points were also digitized on either side of the load cell and referenced to the load cell's rigid body. Three-dimensional coordinates for all digitized locations were continuously monitored throughout data collection by assuming a fixed geometrical relationship between the position and orientation of the segment's rigid body and the digitized location. All kinematic data from the rigid bodies and digitized landmarks were synchronized with the kinetic data and recorded at a rate of 100 Hz.

Protocol

Upon arriving at the lab, participants were asked to complete an 11-item inventory to determine their leg dominance,[20] and their Q-angle was measured.[21] Participants followed a three-minute standardized warm-up consisting of squats, lunges and side-to-side resistance band walks to challenge the muscles targeted during the procedure.[22,23] Following the warm-up, participants were outfitted with the kinematic instrumentation. As a baseline measure, kinematic data were obtained during an upright standing trial prior to beginning the maximal exertion protocol. The participant was instructed to look directly ahead of them while standing with their arms at their side, and feet pointed forward and approximately shoulder width apart.

Participants were then positioned into side-lying on a massage table with their dominant limb on the up side for all hip abduction and adduction strength trials (Figure 1). This position has been shown to be more reliable compared to supine and standing.[24] All exertions were performed with the dominant limb. A strap was placed around the participants' thorax to control its motion and minimize artifacts due to differences in trunk/pelvis orientation between the ascribed hip abduction angles. The participant's non-dominant lower leg was also strapped to the table in addition to manual stabilization of the pelvis provided by an examiner. Foam cushions were used to mitigate lateral bending of the lumbar spine. Investigators positioned the participant and cued them to maintain their body in the frontal plane during all exertions. Participants were also instructed to have their arms crossed to avoid utilizing the upper body and core musculature to generate additional force through muscle irradiation.[25,26] A strap was placed around the ankle of the participant's dominant lower limb and connected to the chain with the load cell.

Participants acclimated themselves to the instrumentation and isometric task by performing several practice trials at submaximal effort. The task required participants to isometrically exert either an upward (hip abduction) or downward (hip adduction) force with a straight leg in 0 degrees of hip flexion/extension and internal/external rotation.[27] After the participant had indicated familiarity with the task, they performed maximal isometric adduction and abduction exertions in the side-lying position at 0, 10, and 20 degrees of ascribed hip abduction. These angles have previously been studied[24,28] and represent angles utilized by ice hockey players. Ascribed hip abduction angles were determined using a goniometer with the stationary arm of the goniometer aligned between both ASISs and the moving arm extended along the long axis of the femur.[7] The 0 degree position was defined as a 90 degree angle between the stationary and moving arms.[29] Each exertion was three seconds in duration with a one-second ramp up to their maximum and a two-second hold at the maximum. Investigators provided verbal encouragement to participants to achieve maximal performance during each exertion. A minimum of two minutes rest was given between each exertion to minimize the potential for fatigue development.[30] Participants were instructed to notify the examiners of any pain during the procedure, as determined by a verbal numeric pain scale.

Each participant performed three abduction trials at each abduction angle and three adduction trials at each abduction angle for a total of 18 maximum voluntary isometric contractions (MVICs). The orders of the ascribed hip abduction angles, and direction of exertion (i.e. abduction or adduction) were administered in a block-randomized manner.

Data Processing and Biomechanical Analysis

Load cell voltages and kinematic data were initially imported to Visual3D (C-Motion Inc., Germantown, MD, USA). Three-dimensional coordinates for the digitized locations from the upright standing trial were used to construct anatomical frames of reference for the shanks, femurs, pelvis, and trunk. Femoral kinematics were determined using the digitized locations for the knee joint and the greater trochanter.[31] Hip joint centers were defined as a quarter of the intertrochanteric distance from the digitized positions for each greater trochanter. Hip joint angle for the dominant lower limb was determined from the relative orientations of the femur and pelvis. The elevation angle of the participant's dominant femur with respect to the lab's horizontal plane was also calculated.

All kinematic data from the isometric exertions were digitally filtered using a dual pass of a second order Butterworth filter with a cutoff frequency of 6 Hz. Load cell voltages were digitally filtered with a dual pass of a second order Butterworth filter at a cutoff frequency of 20Hz before calibration to units of force (Newtons). The direction for the exerted force was determined by mathematically connecting the two digitized points on the load cell. The anatomical point of force application was derived by intersecting the force vector with the shank of the participant's dominant lower limb. Hip adduction and abduction torques were determined using the following equation (1):

$$T = \left\lfloor \boldsymbol{r} \times \left(F \hat{\boldsymbol{v}} \right) \right\rfloor \cdot \hat{\boldsymbol{X}} \qquad (1)$$

In this equation, T = hip torque in the frontal plane; $\boldsymbol{r}$ = moment arm connecting the hip center to the point of force application near the ankle on the participant's dominant lower limb; F = force magnitude; $\hat{\boldsymbol{v}}$ = unit vector representing the force's direction; $\hat{\boldsymbol{X}}$ = unit vector representing the direction of the hip's anterior axis. Peak hip torque was expressed relative to baseline for each exertion.

Hip abduction and femoral elevation angles were obtained at two instances, baseline and peak torque,

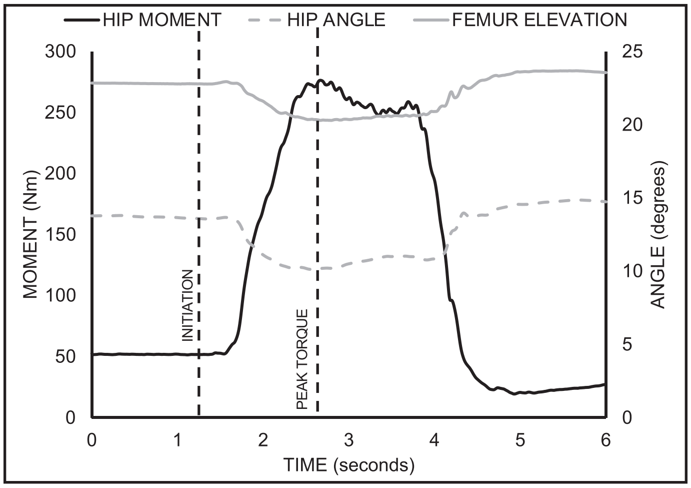

Figure 2. *Sample data of a single adduction exertion at 20 degrees of hip abduction. Hip adduction moment, hip abduction angle, and femur elevation angle are illustrated. The two vertical dashed lines denote the identified points in time for the exertion initiation (baseline) and peak torque.*

for each exertion (Figure 2). Movements of the hip joint and femur during exertion were determined as the relative changes in hip joint abduction and femoral elevation angles from baseline to peak torque. Hip abduction angles and femoral elevation angles at baseline and peak torque, as well as movements of the hip joint and femur for each ascribed hip abduction angle were averaged across the three abduction and adduction trials for subsequent statistical analysis. Averages of the baseline adjusted peak hip torques across the three trials in abduction and adduction at each of the ascribed hip abduction angles were used to derive the adduction to abduction torque ratio. These values were also used as dependent measures in subsequent statistical analyses.

Statistical Analysis

All statistical analyses were performed with SPSS software (SPSS Corporation, Chicago, IL, USA). Descriptive measures (averages and standard deviations) were determined for the hip positions at baseline and peak torque, as well as the change in hip position between baseline and peak torque. A one-way repeated measures analysis of variance (ANOVA) was conducted to identify the effect of ascribed hip abduction angle on the hip adductor-to-abductor torque ratio. A two-way repeated measures ANOVA was performed to determine the effect of exertion direction and ascribed hip angle on the absolute value of the hip torque in the frontal plane. Three additional two-way repeated measures ANOVAs (one for each of the ascribed hip abduction angles) were performed to determine the effects of exertion direction and instance (initiation or peak torque) on the measured hip joint abduction and femoral elevation angles. Pairwise post-hoc comparisons with Holm's adjustments were used to determine differences for dependent measures with a statistically significant main and/or interaction effects. A total of nine paired comparisons were performed as post-hoc analyses for a statistically significant interaction between exertion direction and the ascribed hip angle. Three paired comparisons were performed for a statistically significant main effect of ascribed hip angle on the hip adductor-to-abductor torque ratio. Four paired comparisons were performed for statistically significant interactions between the exertion direction and instance (initiation or peak torque) for kinematic data at each of the three ascribed hip angles. The level of statistical significance was set to 0.05 for all analyses.

RESULTS

Participants

Data were obtained from a total of 12 participants with one participant's data being excluded due to absence of a suitable baseline prior to each exertion. Demographics for all participants are summarized in Table 1.

Kinetic Analysis

All kinetic data are summarized in Table 2. The hip adductor-to-abductor torque ratio increased with increasing hip abduction angle ($p \leq 0.019$). A statistically significant interaction was observed between the ascribed hip angle and the direction of exertion (*p*

Table 1. *Participant demographics (N = 12 males).*

Participant Characteristics	Mean (SD)
Age (years)	25.4 (2.2)
Height (cm)	178.6 (5.2)
Weight (kg)	83.0 (7.4)
Dominant limb	11/12 (R/L)
Q-angle (degrees)	12.1 (1.6)
Hockey experience (years)	20.3 (3.5)

Table 2. *Group averages for hip adductor and abductor torques (Nm) and the adductor-to-abductor torque ratio for the three ascribed hip abduction angles. Standard deviations are presented in parentheses. Italicized values are the adjusted p-values for post hoc paired comparisons of means corresponding to statistically significant interactions between exertion direction and the ascribed hip angle (for torques) or main effects of the ascribed hip angle (for torque ratios). Shaded cells represent potential paired comparisons that were not performed.*

The following are examples for reading the table: For an ascribed hip abduction angle of 10 degrees, the average adductor torque was 247 Nm (standard deviation of 48 Nm) and the average abductor torque was 130 Nm (standard deviation of 21 Nm. These average torques were statistically different from each other ($p < 0.001$). The average adductor torque at an ascribed hip angle of 20 degrees was 246 Nm (standard deviation of 48 Nm), which was not statistically different from the average adductor torque at an ascribed hip angle of 10 degrees ($p = 0.895$). The average adductor-to-abductor torque ratio at an ascribed hip angle of 0 degrees was 1.49 (standard deviation of 0.20), which was statistically smaller than the average ratio of 1.92 (standard deviation of 0.20) at an ascribed hip angle of 10 degrees ($p < 0.001$).

	HIP ANGLE			ADDUCTOR TORQUE 0	ADDUCTOR TORQUE 10	ADDUCTOR TORQUE 20	ABDUCTOR TORQUE 0	ABDUCTOR TORQUE 10	ABDUCTOR TORQUE 20	ADDUCTOR-TO-ABDUCTOR RATIO 0	ADDUCTOR-TO-ABDUCTOR RATIO 10	ADDUCTOR-TO-ABDUCTOR RATIO 20
		MEAN		228	247	246	151	130	111	1.49	1.92	2.3
			(SD)	(49)	(48)	(48)	(22)	(21)	(25)	(0.20)	(0.20)	(0.54)
ADDUCTOR TORQUE	0	228	(49)		*0.019*	*0.016*	*<0.001*					
	10	247	(48)			*0.895*		*<0.001*				
	20	246	(48)						*<0.001*			
ABDUCTOR TORQUE	0	151	(22)					*0.004*	*0.001*			
	10	130	(21)						*0.013*			
	20	111	(25)									
ADDUCTOR-TO-ABDUCTOR RATIO	0	1.49	(0.20)								*<0.001*	*<0.001*
	10	1.92	(0.20)									*0.019*
	20	2.3	(0.54)									

< 0.001). Adduction torque was greater than abduction torque for all three hip abduction angles, which was reflected by all ratios being greater than 1 ($p < 0.001$). Abduction torque decreased with increasing hip abduction angle ($p \leq 0.013$), and adduction torque was lowest for the 0 degree of hip abduction trials ($p \leq 0.016$). There was no difference between adduction torques for the exertions at 10 degrees and 20 degrees of hip abduction ($p = 0.895$).

Kinematics Analysis

Hip angles and femoral elevation angles at initiation and peak torque during each of the six combinations of ascribed hip angle and exertion direction are presented in Tables 3 and 4. Statistically significant interactions between exertion direction and instance were observed for hip angles and femoral elevation angles at each of the three ascribed hip angles ($p \leq 0.037$).

Hip

The average discrepancy between the ascribed hip angle and hip angle at initiation was 2.3 degrees. At initiation, the hip angle was, on average, 4.2 degrees greater for abduction exertions than adduction exertions at 0 degrees and 10 degrees of ascribed hip

Table 3. *Hip abduction/adduction angles (degrees) at the start and at peak exertion for each direction of exertion and ascribed hip angle. Abduction angles are represented by negative values. Standard deviation of the means is represented in parentheses. Italicized values are the adjusted p-values for post hoc paired comparisons of means corresponding to statistically significant interactions between exertion direction and time (initial, peak). Shaded cells represent potential paired comparisons that were not performed.*

The following is an example for reading the table: For an ascribed hip abduction angle of 10 degrees, there was a difference in the hip abduction angle at the start of the exertion (p = 0.002) and at peak exertion (p < 0.001). A statistically significant reduction in the abduction angle occurred between the start and peak of adduction exertions (p = 0.010) and no such change during abduction exertions (p = 0.326).

HIP ANGLE	EXERTION				ABDUCTOR		
0	ADDUCTOR				INITIAL	PEAK	
			MEAN (SD)		-3.1 (4.5)	-4.2 (4.0)	*0.235*
		INITIAL	1.6	(4.7)	*0.007*		
		PEAK	2.8	(4.4)		*0.001*	
			0.135				
10	ADDUCTOR				INITIAL	PEAK	
			MEAN (SD)		-12.5 (2.2)	-13.2 (2.9)	*0.326*
		INITIAL	-8.8	(3.6)	*0.002*		
		PEAK	-6.3	(3.2)		*<0.001*	
			0.010				
20	ADDUCTOR				INITIAL	PEAK	
			MEAN (SD)		-18.2 (3.4)	-20.0 (3.4)	*0.111*
		INITIAL	-16.2	(3.2)	*0.100*		
		PEAK	-12.3	(3.4)		*<0.001*	
			<0.001				

abduction ($p \leq 0.007$). Hip angle at peak torque was also significantly different between abduction and adduction exertions for all three ascribed hip abduction angles (average difference = 7.2 degrees, $p \leq 0.002$). Significant changes in hip angle from initiation to peak torque were also observed for adduction exertions at 10 degrees (average change = 2.5 degrees) and 20 degrees (average change = 3.9 degrees) of ascribed hip abduction ($p \leq 0.010$). There was no significant change in hip angle during abduction exertions at any of the ascribed hip angles ($p \geq 0.111$).

Femur

Femoral elevation at peak torque was greater for abduction exertions than adduction exertions at all three ascribed hip angles ($p \leq 0.002$). Conversely, there were no differences in femoral elevation between abduction and adduction exertions at initiation for any of the ascribed hip angles ($p \geq 0.208$).

Table 4. *Femoral elevation angles (degrees) at the start and at peak exertion for each direction of exertion and ascribed hip angle. Standard deviation of the means is represented in parentheses. Italicized values are the adjusted p-values for post hoc paired comparisons of means corresponding to statistically significant interactions between exertion direction and time (initial, peak). Shaded cells represent potential paired comparisons that were not performed.*

The following is an example for reading the table: For an ascribed hip abduction angle of 10 degrees, there was no difference in the femoral elevation angle at the start of the exertion (p = 0.402) and a statistically significant difference at peak exertion (p < 0.001). A statistically significant reduction in the femoral elevation angle occurred between the start and peak of adduction exertions (p = 0.002) and a statistically significant increase during abduction exertions (p = 0.001).

HIP ANGLE	EXERTION				ABDUCTOR		
					INITIAL	PEAK	
0					9.0 (4.2)	12.1 (3.8)	*<0.001*
		INITIAL	7.6	(2.4)	*0.208*		
		PEAK	6.2	(2.7)		*0.002*	
			0.001				
					INITIAL	PEAK	
10					20.5 (2.8)	23.4 (2.5)	*0.001*
	ADDUCTOR	INITIAL	19.9	(3.4)	*0.402*		
		PEAK	17.9	(3.2)		*<0.001*	
			0.002				
					INITIAL	PEAK	
20					28.0 (2.6)	31.6 (2.1)	*<0.001*
		INITIAL	27.1	(3.2)	*0.361*		
		PEAK	24.8	(3.4)		*<0.001*	
			<0.001				

Femoral elevation angle changed significantly from initiation to peak torque for all six combinations of ascribed hip angle and exertion direction ($p \leq 0.001$).

DISCUSSION

Previous studies have investigated the change in hip abduction and adduction force with different hip abduction angles.[9] The current study was the first to directly demonstrate that hip abduction angle can significantly influence the hip adduction-to-abduction torque ratio. Furthermore, this investigation was the first to the authors' knowledge to evaluate patient positioning and monitor the kinematics of the lower limb, pelvis, and thorax during maximal isometric hip abduction and adduction exertions. This information is particularly useful considering that the hip adductor-to-abductor torque ratio has been used to determine potential injury risk.

Manual muscle testing is widely used by many health practitioners during pre-season testing to guide training or rehabilitation.[32-35] Agonist-antagonist strength

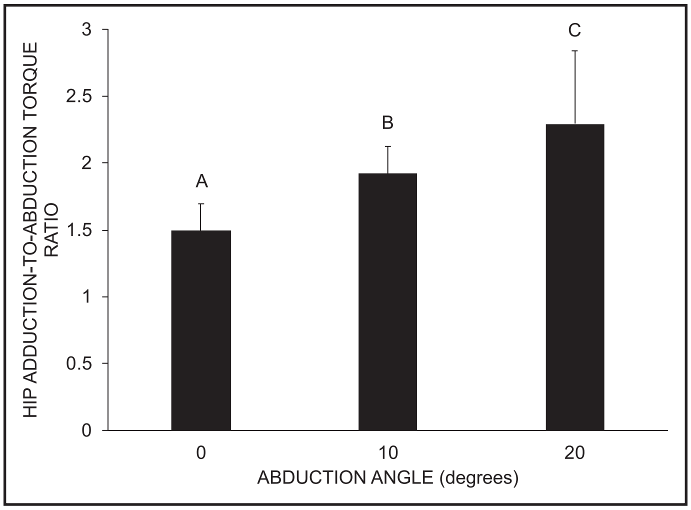

Figure 3.

ratios from these tests are often used to inform injury risk, as demonstrated in hockey players,[7,12] soccer players,[4] and Gaelic football players.[33] The ratios reported in the current investigation were higher than those reported in previous studies that used hockey and soccer players;[7,36,37] however direct comparisons should not be made due to differences in the testing parameters. Tyler and colleagues[7] performed adduction trials with the athlete in a side-lying position and the hip adducted, which may reduce the force-producing capacity of the adductor muscles. Furthermore, these authors performed abduction trials with the hip abducted "above horizontal". This discrepancy in hip posture for the adduction and abduction trials possibly provided a mechanical advantage to the hip abductors compared to the testing position of the adductors. Hip adduction-to-abduction ratios in the current investigation were determined for the same ascribed hip abduction angle. This decision was made due to the fact that co-contraction at a given angle is an important aspect of normal joint motion.[38] An acute muscle injury, such as a hip adductor strain, occurs at a given joint angle, most often in the eccentric phase of the hockey stride as the hip moves into an abducted position.[39] Therefore, testing two opposing muscle groups at the same joint angle is likely more representative of the interaction between these muscle groups when an injury occurs. Although the hockey stride involves a combination of hip abduction, extension, and external rotation, the intention for this study was to evaluate the abduction-adduction component as a risk factor for injury. Therefore, hip extension or external rotation strength were not tested in the current investigation.

An optoelectronic motion-capture system provided data to allow the authors to monitor three-dimensional orientations for the lower limbs, pelvis, thorax, and the direction of the exerted force during all trials in this investigation. The kinematic information allowed the authors to derive the hip torque exerted in the frontal plane during each trial. This analysis accounts for differences that might occur in the direction of the exerted force and the point of application on the lower limb.

Measuring kinematics of the lower limbs, pelvis, and thorax also provided an opportunity to determine the accuracy of the ascribed hip abduction angles at both initiation and peak torque during exertions, as traditional goniometric assessments of the hip tend to overestimate hip ROM.[40] Measured hip angles at the initiation of exertions accurately matched the ascribed hip angles, but were different between abduction and adduction exertions. Conversely, femoral elevation angles at the initiation of exertions were greater than their expected elevation (e.g. a femoral elevation angle of 10 degrees would be expected for exertions with an ascribed hip abduction angle of 10 degrees). Furthermore, there were no statistically significant differences in the femoral elevation angle at the initiation of the abduction and adduction exertions. These conflicting findings indicate that the observed differences in hip posture at the initiation of abduction and adduction exertions was likely the result of pelvic positioning at the initiation of the exertions. Monitoring the kinematics throughout the test also allowed for an investigation into the extent to which the isometric nature of the task was maintained. Small (average changes of 2.5 degrees and 3.9 degrees), yet statistically significant, changes in hip posture were observed for adduction exertions performed with 10 and 20 degrees of ascribed hip abduction. The small changes in hip posture indicate that the isometric nature of the task was adequately maintained by the experimental setup. Overall, any movement of the hip joint was consistent with the direction of exertion (i.e. hip abduction decreased during adduction exertions and increased during abduction exertions).

There are several limitations to this study. First, only male hockey players were utilized and therefore this work cannot be extrapolated to female hockey players. Studies have shown reduced abductor torque in female youth athletes compared to male youth athletes.[41] It is possible that due to anatomical differences of the pelvis and Q-angle in females that the adductor-to-abductor ratio may differ in this population. The small sample size and cross-sectional design also prevents the use of this data for normative or injury risk factor purposes. Other limitations pertain to the experimental setup and protocol. The decision to evaluate abduction and adduction torque in a lateral recumbent position was consistent with the position used by Tyler and colleagues.[7] Previous work has demonstrated that the lateral recumbent position is the most reliable method for evaluating isometric hip abduction strength.[24] Furthermore, a rigid mechanical restraint was used to ensure that the exertions were isometric.[24] This may reduce the clinical validity of findings presented in the current investigation; however, previous work has recommended the use of an externally fixed dynamometer (i.e. rigid mechanical restraint) on the basis that intertester bias exists when using a handheld dynamometer.[42,43] Finally, this study did not test the hip in an adducted position, which is commonly used clinically, because a decision was made to test strength in ranges-of-motion representative of ice hockey.[44]

CONCLUSION

The results of this study demonstrated that the hip abduction angle has a significant impact on the adductor-to-abductor strength ratio, therefore the ability of this ratio to determine injury risk could be dependent upon the angle at which the hip muscles are tested. The adductor-to-abductor strength ratio is a reported risk factor for adductor strain; however, previous work has provided insufficient details regarding hip positioning and joint angles as well as a rationale for the chosen testing parameters. The value of using this ratio to infer injury risk may be limited by the data collection methods and clinicians should use caution when interpreting the ratio when the testing parameters are not standardized. Using one angle to test both adduction and abduction is likely to be more representative of the agonist/antagonist relationship between opposing muscles. While the chosen angle can vary, it should fall within the functional range of the task or the position in which an injury most often occurs. In addition, this study demonstrated that femoral and hip posture can change during the exertion, which changes the intended hip position of this test. Because of this finding, we recommend that specific measures are taken to stabilize the pelvis and femur during isometric testing of the hip, as many studies do not adequately address this compensatory motion.[27,45]

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