

Gender Differences in Hip Adduction Motion and Torque during a Single-Leg Agility Maneuver

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ABSTRACT: The purpose of this study was to identify gender differences in hip motion and kinetics during a single leg bidirectional deceleration maneuver. The rationale for the development of this maneuver was to test dynamic hip control during the deceleration of three different types of single-leg landings. The hypothesis was that female athletes would display increased hip adduction angles and moments during the maneuver compared to male athletes. Thirty-six collegiate soccer players (19 female, 17 male) volunteered to participate. Subjects were instructed to start the maneuver balancing on one foot, to hop through an agility-speed ladder on the same leg "up two boxes, back one, and then up one and hold it." Hip kinematics and kinetics during all three landings were examined. Females demonstrated significantly greater hip adduction angles at initial contact during all three landings and greater maximal hip adduction during landings 1 and 2 compared to male athletes. Females also exhibited significantly increased external hip adduction moments during landing 1, however, no differences were found between genders during landings 2 and 3. © 2006 Orthopaedic Research Society. Published by Wiley Periodicals, Inc. *J Orthop Res* 24:416–421, 2006

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INTRODUCTION

Female athletes are four to six times more likely than male athletes to tear their anterior cruciate ligament (ACL) playing similar landing and pivoting sports.^{1,2} The effects of neuromuscular training on equalizing injury risk indicates that neuromuscular control of the knee plays a major role in the determination of gender-specific injury risk.^{3–5} ACL injuries occur with most or all of the weight shifted to a single foot.⁶ Therefore, gender differences in hip position and neuromuscular control during single-leg landing may contribute to the increased incidence of ACL

injury in female athletes, as control of hip joint stability affects the dissipation of knee joint loading during athletic tasks.

Female athletes demonstrate increased knee abduction (valgus) motion and moments compared to male athletes during athletic maneuvers.^{7–10} During landing, a greater valgus moment at the knee predominates in females, while a varus moment dominates in males.¹¹ Measures of valgus during landings are related to increased risk of ACL injury.¹²

Ground reaction forces can reach several times body weight during landing.^{9,13} Excessive landing force, if inadequately absorbed, may be an important contributor to ACL injury risk.¹⁴ Hip and knee angles during landing may be important determinants of impact force at the knee.^{15–17} During landing, the hip extensor eccentric contraction can absorb 22% of the body's total kinetic energy.¹⁸

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Increased valgus torques significantly correlate to high peak impact forces during landing.⁹ Neuromuscular training can reduce both valgus moments and peak impact forces.^{9,19} Increased ability to decelerate from a landing and control knee valgus may be related to hip muscle strength and recruitment.²⁰ Increased strength and recruitment of the hip musculature may protect the ACL in female athletes. Adequate recruitment of the hip abductors may help control high knee abduction torques or valgus collapse.

The combined positioning of increased hip adduction and knee valgus may predispose women to ACL injury.^{12,21–23} Functioning eccentrically, the hip abductor muscles may play an important role in controlling excessive valgus knee motion and torque in females. The hip abductor musculature may help to counteract the biomechanical changes that occur in females during puberty (longer lever arms at the tibia and femur and greater and higher center of mass), when ACL risk significantly increases in female athletes.^{4,19,24–26}

The purpose of this study was to identify differences in hip motion (kinematics) and moments (kinetics) between male and female collegiate athletes during the physically demanding bidirectional single-leg deceleration maneuver. The rationale for the development of this maneuver was to test dynamic hip control during the deceleration of three different types of single-leg landings. The hypothesis was that female athletes would display increased hip adduction angles and increased external adduction moments (indicative of decreased hip abduction muscle torque) compared to males during the single leg agility maneuver.

MATERIALS AND METHODS

Thirty-six collegiate soccer players (19 female, 17 male) volunteered to participate in this study (Table 1). All subjects were from the same university (Division I) and were currently on the men's or women's team roster.

Table 1. Demographic Data for the Study Groups

Characteristic	Male (N = 17)		Female (N = 19)	
	Mean	SD	Mean	SD
Age (years)	21.4	1.6	20.0	1.2
Height (m)	1.77	0.1	1.65	0.1
Weight (kg)	74.1	6.7	66.1	10.1
BMI	23.7	1.5	24.1	2.6

Each subject read and signed the informed written consent, approved by our Institutional Review Board, prior to participation. Height, weight, and dominant leg were assessed. The dominant leg was determined for each subject by asking which leg they would use to kick a ball as far as possible.⁷

Eight high-speed Eagle video cameras (Motion Analysis Corp., Santa Rosa, CA) were positioned in the laboratory to capture a volume optimized to $4.5 \times 2 \times 2.5$ m. Two force platforms (AMTI, Watertown, MA) were embedded into the floor and positioned 8 cm apart. Video and force data were time synchronized and collected at 240 Hz and 1200 Hz, respectively (EVaRT, Motion Analysis Corp.). Twenty-five retro reflective markers (2 cm) were secured to each subject with double-sided electrode tape and positioned on the sacrum and bilaterally on the shoulder, ASIS, greater trochanter, mid thigh, medial and lateral knee, tibial tubercle, mid shank, medial and lateral ankle, heel, and toe (between second and third metatarsals). An agility-speed ladder (Myrland Sports Training, LLC, Middleton, WI) was positioned in the motion capture volume and aligned so that the landings would occur on one of the force platforms (Fig. 1). The motion analysis system was calibrated to manufacturer recommendations prior to each data collection session.

The single-leg agility maneuver was demonstrated, and each subject was allowed to practice the maneuver on both their dominant and nondominant side. The subjects were instructed to start the maneuver balancing on one foot and to hop on that same leg “up two boxes, back one, and then up one and hold it” (Fig. 1). They were further instructed to perform the maneuver as fast as they could without touching the ladder, losing control, or putting their other foot down. Six randomized trials, three on each side, were collected for each subject. Trials were discarded if subject's landed on the ladder or were not entirely on a force platform. The test maneuver was chosen to evaluate gender differences when performing a difficult agility maneuver. The maneuver allowed for kinematic and kinetic analysis of three distinctly different single-leg limb landings and the effect that gender had upon each of the measures.

Motion and force data were imported into KinTrak (Version 6.2, Motion Analysis Corp.) for reduction and analysis. The three-dimensional Cartesian marker trajectories from each trial were estimated using the direct linear transformation method. The video and force data were filtered at the same cutoff frequency (12 Hz) using a second order low-pass Butterworth filter.²⁷ Initial contacts (IC) from the first three landings were identified when the vertical force exceeded a threshold of 10 N. Likewise, toe off (TO) was identified as the point when the vertical force lowered below the threshold of 10 N. The time between the three IC and TO, respectively, were designated landings 1, 2, and 3 (Fig. 1).

A static trial was collected prior to the single leg agility maneuver trials. Joint coordinate systems were

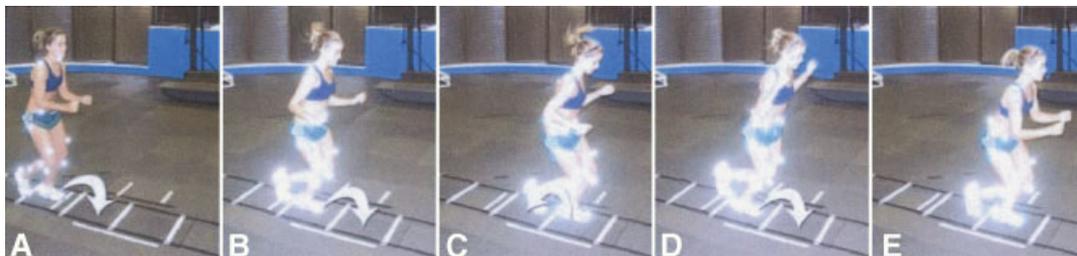


Figure 1. Single leg bidirectional deceleration maneuver demonstrated.

then constructed for each subject based on the static trial. Hip center was located according to Bell et al.,²⁸ while the knee joint center was identified as the midpoint between the medial and lateral knee joint markers.²⁹

Hip flexion and adduction angles were calculated from an embedded joint coordinate system.³⁰ The maximum angle during the initial stance phase was recorded. Moments were calculated from the motion and force data using inverse dynamics.³¹ External moments are described in this article as external forces acting on the body. Maximum moments during each stance phase were calculated and normalized to body mass times height.

Statistical means and standard errors of the mean for each variable were calculated for each subject. A two-way mixed design ANOVA was used to determine the main effects and interaction of gender and side on each dependent variable ($p < 0.05$). A post hoc paired t -test, split by gender, was used when a significant interaction was found. Statistical analyses were conducted using SPSS (SPSS for Windows, Release 11.5).

RESULTS

Females had significantly greater hip adduction angles at initial contact during all three landings compared to males (Fig. 2). Females demon-

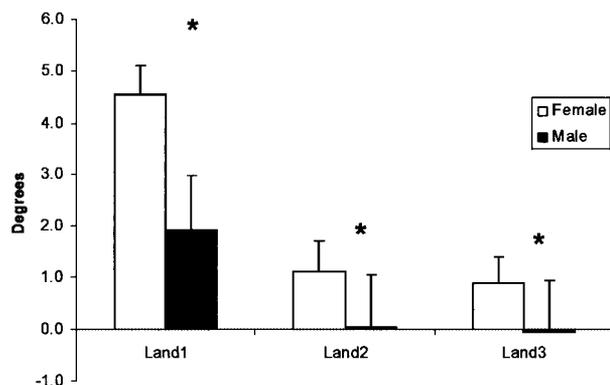


Figure 2. Hip adduction angle at initial contact on the dominant side for each landing ($*p < 0.05$).

strated 1.3 and 2.6 times greater hip adduction angles at IC than males during the first landing.

Females had significantly greater maximal hip adduction during landings 1 and 2 (Fig. 3). Females demonstrated 100% higher maximal hip adduction when averaged over all three landings than males. Females also exhibited significantly greater external hip adduction moments during landing 1 (Fig. 4); however, no differences were found between genders during landings 2 and 3.

In contrast to the frontal plane angle and moment findings, no gender differences occurred in hip flexion angles (IC or maximum) during any of the landings. Finally, no significant differences were observed in the transverse plane (in internal or external rotation kinematics or kinetics) during any of the landings. The significant gender differences observed were limited to the coronal plane.

DISCUSSION

The purpose of this study was to determine whether females and males demonstrate differences in hip joint control and mechanics during the physically demanding task of single-leg land-

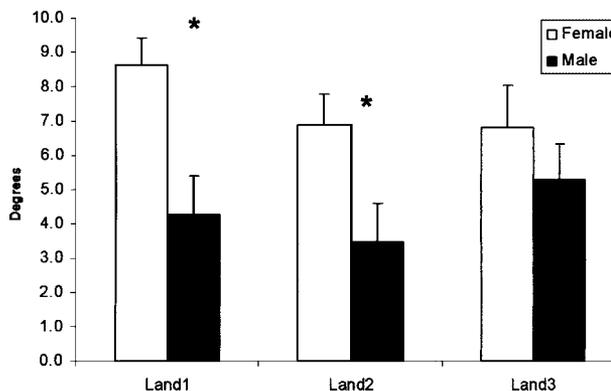


Figure 3. Maximum hip adduction angle for the dominant side observed during each landing ($*p < 0.05$).

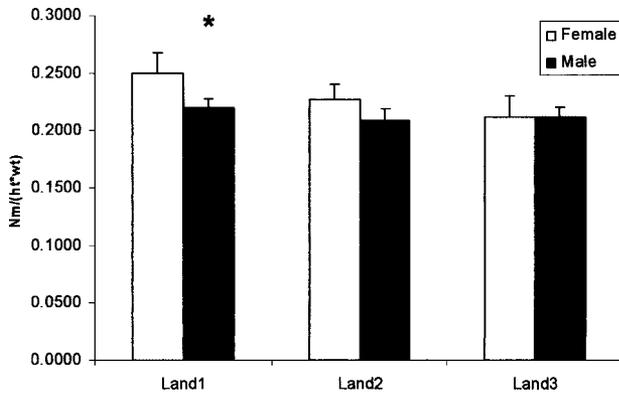


Figure 4. External hip adduction movement in Newton-meters normalized to height and weight (* $p < 0.005$).

ing during bidirectional (forwards and backwards) hopping. The hypothesis that female athletes would display increased hip adduction angles during multiple deceleration landings was supported by our findings. This observed decrease in hip coronal plane control likely contributes to the observed lower extremity valgus alignment exhibited in female athletes with increased risk of ACL injury.¹²

The results of our study also demonstrate that female athletes have greater external hip adduction moments during landing. The increased external hip adduction moment indicates that females control the hip, especially in resistance to adduction forces during dynamic sports movement, differently than male athletes. Considering the dynamic coupling between segments of the kinetic chain, asymmetry of hip abductor and adductor muscle activation may lead to the valgus position of the knee exhibited in female landing patterns.⁷⁻¹⁰

Inadequate hip adductor strength and/or recruitment may be responsible for positioning the lower extremity in femoral adduction, hip internal rotation, and knee valgus in female athletes.^{12,20,34} Dynamic neuromuscular training decreases landing forces as well as decreases valgus and varus torques.^{9,19} Preparticipation screening for excessive valgus motion may allow for the ready assessment for decreased dynamic knee control in female athletes.⁷ Screening for decreased dynamic knee control may be critical for the identification of female athletes who would benefit from specific training to proximal stabilizing muscles.^{12,20,32,34} Correction of neuromuscular control deficits at both the proximal and distal musculature is important for optimal biomecha-

tics and safe landing positions to reduce the disproportionate ACL injury incidence in female athletes.^{9,33} Enhancing the activation of the hip musculature may help correct excessive hip internal rotation, adduction, and resultant valgus knee positioning, and may help reduce noncontact ACL injuries.²⁰ Advances in the prevention of ACL injuries in females are necessary for females' safe participation in high risk cutting and landing sports like volleyball, basketball, and soccer.

The present study has limitations. The lack of a significant difference in sagittal and transverse planes hip motion and moments could be attributed to our small number of subjects. Another limitation is the absence of electromyographic measures to add confirmatory evidence to our kinematic and kinetic data.³⁴ These combined measures should be undertaken in future studies.

This study compared and analyzed hip motion and moments during a bidirectional hopping task. Future studies could include a combined evaluation of the lower extremity and trunk, specifically correlating hip muscle activity with hip and trunk kinematics and kinetics, including frontal, sagittal, and transverse plane measures. Similarly, an experimental analysis of the effects of neuromuscular training specifically targeted to hip and trunk stabilizing muscles would provide insight into the gender disparity in ACL risk. A study using kinematics, kinetics, and EMG could determine if hip muscle activation in females can be altered by neuromuscular training.

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