GENERALIZED JOINT HYPERMOBILITY ALTERS FRONTAL PLANE KNEE JOINT LOADING IN FEMALE COLLEGIATE DIVISION 1 LACROSSE ATHLETES

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Generalized joint hypermobility (GJH) has been defined as a form of joint laxity that affects an individual systemically, with 5-43% of individuals in the population affected. These individuals experience injuries at a higher frequency and severity than the normal population. The purpose of this investigation was to determine if female collegiate division I lacrosse players with GJH demonstrated different knee mechanics than matched controls. Kinematic and kinetic data were collected as participants performed a single leg land and cut task. The GJH group demonstrated greater peak internal knee adductor moments during landing and a trend toward greater knee extensor moments, which has been reported as a deleterious pattern of loading with increased risk for non-contact anterior cruciate ligament injuries.

KEYWORDS: ACL, Beighton's, Landing

INTRODUCTION: Generalized joint hypermobility (GJH) has been defined as a form of joint laxity that affects individuals systemically (Carter & Wilkinson, 1964) and is thought to occur from genetic difference in the collagen makeup of these individuals (Russek, 1999). Severe forms of hypermobility are found in Ehlers-Danlos syndrome and Marfans syndrome. Unlike these severe forms of hypermobility, individuals with GJH are generally not impacted during activities of daily living and are often referred to in common vernacular as "double-jointed." A greater incidence of GJH is found in females and children (Russek, 1999). GJH is also reflected in the athletic population, where in recent investigations anywhere from 5% to 43% of the female athletes demonstrate signs of GJH (Decoster, Bernier, Lindsay, & Vailas, 1999; Konopinski, Jones, & Johnson, 2012; Pacey, Nicholson, Adams, Munn, & Munns, 2010). There is growing evidence that athletes with GJH are at greater risk of knee injury during athletic participation, and there is an additional association with more frequent and more serious injuries (Konopinski et al., 2012; Pacey et al., 2010). There is also evidence that individuals with GJH exhibit difference in their muscle activation during gait (Schmid et al., 2013; Simonsen et al., 2012) and joint energetics during landing (Shultz, Schmitz, Nguyen, & Levine, 2010). However these investigations were done with individuals from the general population. There has been no published investigation of joint mechanics in athletic individuals with GJH during athletic types of movements. The purpose of this investigation was to identify differences in the joint mechanics of the knee in women's collegiate division I lacrosse athletes during a single leg land and cut task, when compared with matched controls from the same team.

METHODS: Following acquisition of informed consent, all healthy uninjured women's lacrosse players on the University roster were tested for GJH utilizing Beighton's score (Juul-Kristensen, Rogind, Jensen, & Remvig, 2007). The Beighton's score consists of a series of measurements of joint motion, including hyperextension of the knees and elbows, dorsal flexion of the 5th digit, 1st digit and forearm approximation, and the ability to touch the palms flat to the floor with the knees maintained in full extension, for a total of 9 signs. Five or more positive signs were needed for inclusion in the GJH group (Decoster et al., 1999). The experimental (GJH) group consisted of 7 players (19.4±1.0yrs, 66.0±6.1kg, 167.3±3.3cm) with a 5 or greater Beighton's score (range 5-7, mean 6.0). Seven matched controls (19.9±1.2yrs, 62.1±7.1kg, 165.3±7.3cm) were included with zero or one positive Beighton's score (range 0-1, mean 0.1). Participants were then fitted with 20 individual reflective markers to define joint centers and bilateral thigh, shin, and heel clusters of 4, 4, and 3 markers for a standing trial. All markers except the marker clusters, ASIS and PSIS markers were removed for tracking segment motion during data collection. Participants were then asked to perform a single leg cutting task as follows: participants stood on a platform normalized to their vertical jump height and set away from the force plate a distance normalized to one maximum single stride length. Participants jumped forward leading with their right leg and landed in the middle of the force plate, then immediately performed a 90 degree cut to the left. Three-dimensional kinematic data were captured at 120Hz with a 14-camera motion analysis system (Vicon Inc. Oxford, UK), with simultaneous collection of kinetic data at 960Hz using a floor embedded forceplate (AMTI Corp. Watertown, MA). Kinematic and kinetic data were filtered using a 4th order low pass Butterworth filter with a cutoff frequency of 12 Hz. A 3D kinematic model was built in Visual 3D software (C-motion Inc, Germantown, MD). Hip, knee, and ankle joint centers were defined respectively as 25 percent of the horizontal distance between trochanter markers, midpoint of medial and lateral knee markers, and midpoint of medial and lateral malleoli markers. Using this model, joint angles were calculated during each trial. Joint moments were calculated using an inverse dynamics approach in Visual 3D software. A custom Matlab (Mathworks Inc, Natick, MA) program was used for data compilation and extraction. Statistical analysis were performed using SPSS (SPSS, Chicago, IL). Paired t-tests were used to analyze between group differences using a p<0.05 level of significance. Dependent variables analyzed were knee joint angle at initial contact, knee range-of-motion during the stance phase, and peak knee joint moment during the stance phase, all in 3 planes of motion. Further analysis was done on the joint moments during the initial 20 percent of stance phase, as that is the timeframe during which most non-contact ACL injuries are thought to occur. All joint moments are reported as internal moments. No statistical correction was used with the multiple number of t-tests, as the study was exploratory in nature and included small numbers. Thus the risk of a Type II error was deemed more detrimental to understanding the study results in this population than the risk of a Type I error (Perneger, 1998).

RESULTS: The GJH group knee angles at initial ground contact were not different from controls in the sagittal (-20.7±3.9, -21.6±4.4 degrees, p=0.58) or frontal planes (1.8±3.6, 3.0±3.9 degrees, p=0.27). The GJH group did demonstrate a statistically significant difference in knee external rotation, with the GJH group's knee ER being less than controls (-7.1±3.9, -13.2±2.4 degrees, p=0.03).
The GJH group exhibited significantly less ROM in the frontal plane during the ground contact time (11.9±3.4, 17.5±3.5 degrees, p=0.01). Post hoc analysis revealed that this ROM difference was from a decreased peak varus knee angle during mid-stance (5.6±5.0, 11.8±4.3 degrees, p=0.01). The GJH group trended toward less ROM in the transverse plane (16.0±4.9, 22.2±5.6 degrees, p=0.06). Post hoc analysis revealed that after the GJH group landed in less tibial external rotation at initial contact, both groups reached a similar degree of tibial internal rotation as stance progressed (8.5±4.8, 8.3±5.3 degrees , p=0.93).
The GJH group experienced significantly greater peak knee adductor moments than controls (37.0±10.4, 24.6±9.2 N-m, p=0.02) and smaller peak knee abductor moments (-44.9±23.5, -70.8±12.1 N-m, p=0.02). Additionally, during the first 20 percent of ground contact time, the GJH group demonstrated greater peak knee adductor moments (5.7±11.0, -21.2±14.1 N-m, p<0.01). The GJH group trended towards greater peak knee extensor moments (213.3±36.5, 170.8±29.5 N-m, p=0.06).

DISCUSSION: Epidemiologic studies report that individuals and athletes with greater GJH experience more frequent and more severe injuries to the knee (Pacey et al., 2010). In this investigation, differences noted in the knee mechanics of the GJH participants during the land-cut task were consistent with patterns associated with greater risk for non-contact ACL injuries (Hewett et al., 2005). This is also consistent with the work of Shultz et al., who reported an association between GJH and landing strategies that increase the stiffness and energy absorption at the knee during the landing phase of a bilateral drop-jump (Shultz et al., 2010). This is also somewhat in agreement with Simonsen et al., who report an increase in joint moments at the knee in the GJH group during gait (Simonsen et al., 2012).

Perhaps most interesting is that when individual participant frontal plane moments during the first 20 percent of stance are graphed sequentially in order from most positive knee frontal plane moment (adductor moment) to most negative (abductor moment), participants in the GJH group comprise the first 6, and the final GJH participant 10th (figure 1). The consistency of the pattern is noteworthy, especially given the association in the literature between increases in knee adductor moments and risk of ACL injury (Hewett et al., 2005).

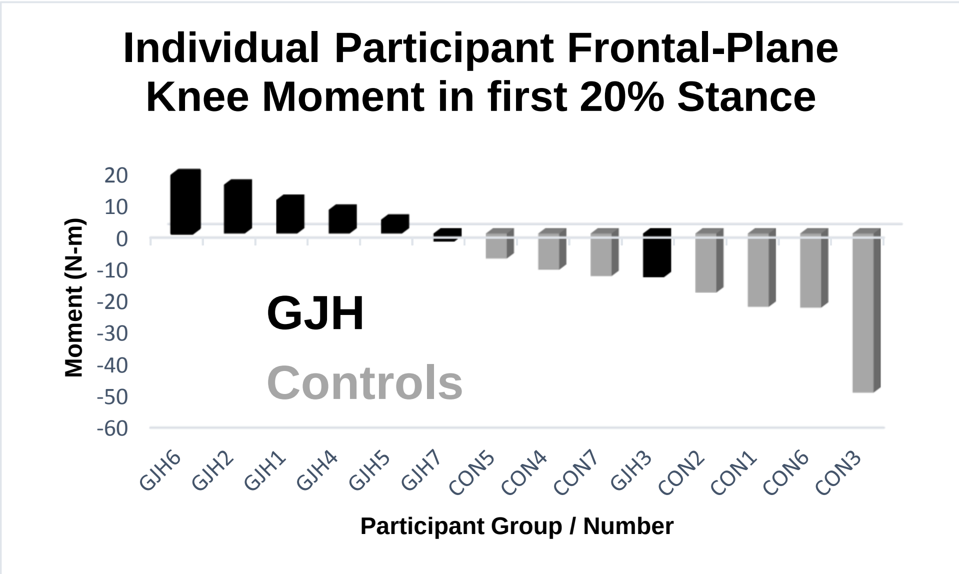

Figure 1: Individual participant frontal-plane knee joint moments for experimental group (black, GJH), and matched controls (grey, CON). Positive numbers are internal adductor moments, negative numbers are internal abductor moments.

CONCLUSION: Individuals with GJH demonstrated greater knee adductor moments during the initial landing phase of a land and cut task compared to controls and a trend toward greater knee extensor moments. These findings may provide insight into why individuals with GJH more frequently experience knee injuries in athletics. Future work should expand on the participant pool, evaluate the other joints in the kinetic chain, and evaluate for muscle activation pattern differences in the performance of athletic activities in this experimental group. Practitioners working with athletes should be aware of differences in individuals with GJH, and pay particular attention to landing mechanics during training.

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