INDIVIDUALS WITH GENERALIZED JOINT HYPERMOBILITY DEMONSTRATE SIMILAR LOWER EXTREMITY MUSCLE FORCES DURING A DYNAMIC CUTTING TASK

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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 muscle forces than matched controls during a demanding athletic-like task. EMG, kinematic, and kinetic data were collected as participants performed a single leg land and cut task. The GJH group demonstrated overall similar muscle forces in the lower extremity to controls. This is unexpected given the need for joint stability in the lower extremity of those individuals with greater generalized joint laxity.
KEYWORDS: ACL, hypermobility, GJH, athlete, OpenSim

INTRODUCTION: Generalized joint hypermobility (GJH) is defined as a form of systemic joint laxity thought to occur from genetic difference in the collagen makeup of these individuals (Grahame, 1999). Severe forms of hypermobility are a component of Ehlers-Danlos syndrome and Marfan syndrome. However, unlike these often-debilitating 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.” Traditionally, investigators group individuals into a hypermobile group or a non-hypermobile group according to their Beighton Score. Beighton Score is a series of yes or no criteria, including whether the individual’s elbows and knees hyperextend past 10 degrees, 5th digits extend past 90 degrees, thumbs can touch the forearm, and the individual can touch their palms easily to the floor with knees straight, for a total of 9 signs (Beighton and Horan, 1969). Most studies group individuals with 5 or more of these signs into the “hypermobile” group. GJH is reflected in the athletic population, where the incidence of GJH among female athletes is estimated to be as high as 43% (Birrell et al, 1994). There is growing evidence that athletes with GJH are at greater risk of knee injury during athletic participation (Pacey, 2010), and that overall, they are injured more frequently and for longer periods of time (Konopinski, 2012). Previous investigators have attempted to pinpoint differences in the movement of individuals with GJH to identify a direction for interventions. Alterations in kinetic variables and muscle activation patterns have been reported in the GJH population during gait (Schmid, 2013) and during landing from a jump (Shultz, 2010). However, the individual muscle contributions to joint control and stability during activity in this group of individuals has not previously been investigated or simulated. The goal of the current investigation was to examine the impact of GJH on individual lower extremity muscle force contributions in high level athletes during a strenuous task.

METHODS: Thirty-eight athletes from a women’s Lacrosse team were screened for GJH using the Beighton and Horan Joint Mobility Index (BHJMI). Individuals with a score of 5 or greater were assigned to the GJH group (Decoster, 1999). Individuals with scores of 0 were used as controls, and those with scores of 1 to 4 were excluded from the study. Seven women had a score of 5 or more on the BHJMI (GJH group: 19.4±1.0 years, 66.0±6.1 kg, 167.3±3.3 cm). Eight controls from that same team had a score of 0 or 1 on the BHJMI (CTRL group: 19.9±1.2 years, 62.1±7.1 kg, 165.3±7.3 cm).

Eight wireless surface EMG sensors were placed on each players’ dominant side Gluteus Maximus and Medius, Rectus Femoris, Vastus Lateralis and Medialis, Biceps Femoris, Medial Gastrocnemius and Anterior Tibialis of each subject. Leg dominance was determined by asking which leg they prefer to kick a ball with (right leg in all subjects). The skin was prepared by cleaning with an alcohol wipe and allowed to dry prior to electrode placement. No subjects needed shaving. Sensors were applied with manufacturer adhesives strips and reinforced with flexible adhesive tape. 3D kinematic data were collected via a 14 camera Vicon system (Vicon Inc. Oxford, UK) at 120 Hz with kinetic data collected at 960 Hz (AMTI Corp. Watertown, MA) in the same Vicon system. EMG data were collected simultaneously in Vicon through a wireless Delsys Trigno EMG system (Delsys, Natick, MA) at 960 Hz.

Subjects performed a single-leg land-and-cut (CUT) task in the lab while EMG, kinematic and kinetic data were collected. The CUT task involved standing on a box, jumping forward and landing on the dominant leg, and cutting immediately 90 degrees away from the landing leg. The height of the box was set equal to each subject's max vertical jump height, as measured from the displacement of a pelvis marker during a maximum countermovement jump. The box was set back from the force plate a distance equal to each participant's maximum single leg stride distance. This task was chosen because it was a challenging single-leg, athletic-like task that still allowed expedient data collection in a controlled lab setting. To avoid biasing subjects, the same instructions to "land and quickly cut to the left" were given to each subject. Participants were allowed to practice the task until comfortable, and then performed 3 successful trials. Trials were deemed unsuccessful if the subject could not complete the task, or if they turned and faced the CUT direction instead of facing forward.

Data were exported for analysis with custom Matlab software. Data were filtered in Matlab using a Bandpass filter with cutoff frequencies of 10Hz to 400Hz. GRF data were used to determine the stance phase of cutting. The stance-phase EMG data for all muscles were time normalized, and ensemble averages were calculated for each of the 8 muscles.

A musculoskeletal model (Xu, 2015) including multiple degrees of freedom was scaled to create subject-specific segment parameters in OpenSim. Inverse kinematics were used to calculate joint angles by minimizing position of model markers and position of subject markers in OpenSim. Static optimization was used in OpenSim to estimate muscle forces and activations by minimizing a sum of squared activations of all muscles, and these data were exported. The simulated muscle activations from static optimization were compared to EMG data (figure 1) for the muscles which were monitored with EMG. We then grouped simulated muscle force data into seven functional groups: GMax (anterior, medial, and posterior fibers of gluteus maximus), GMed (anterior, medial, and posterior fibers of gluteus medius), HAM (semitendinosus, semimembranosus, and biceps femoris long head), QUAD (rectus femoris, vastus lateralis, medialis, and intermedius), CALF (soleus, medial and lateral gastrocnemius), TA (tibialis anterior), and EVERT (peroneus longus and brevis).

Statistical Parametric Mapping (SPM) was utilized for statistical comparison between the normalized muscle forces for GJH and controls over the ground contact time, largely because SPM utilizes the entire curve for analysis, unlike discrete variables that ignore all but one time point on a set of continuous data. SPM uses the variability across each trial to create a critical "t" threshold to evaluate differences at each point in the curve (Friston, 1994). Any period where the t-value was above the critical threshold is identified as a statistical difference ($p<0.05$). Inherent to SPM is some control and consideration for multiple comparisons across the entire time curves (Friston, 1994). Statistical comparisons were calculated for each muscle and also for each muscle group in Matlab using a custom written script.

RESULTS: Calculated muscle activations from the model appeared to largely resemble the shape of measured EMG activation curves for the muscles monitored (figure 1), and the joint moment curves largely mirrored the modelled muscle forces for groups responsible for the internal moments, such as the quadriceps muscle group and the knee extensor moment curves. Thus, the model was judged to have acceptable validity for this type of analysis (Hicks, 2015).

SPM analysis of model-derived normalized muscle forces demonstrated no major differences between GJH and Controls for individual muscle forces (figure 2) or combined muscle group forces (figure 3).

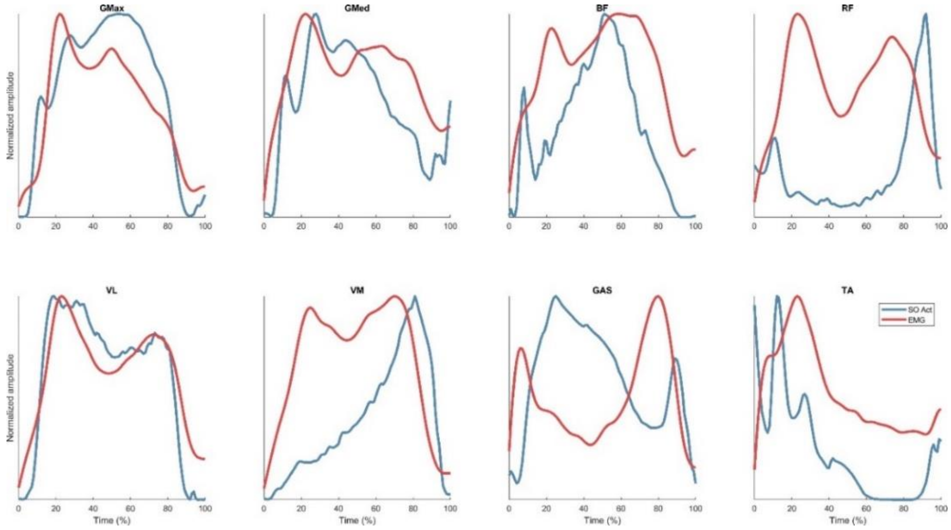

Figure 1: Model (calculated) muscle activation from static optimization vs sEMG (measured) activation during the ground contact phase of CUT task.

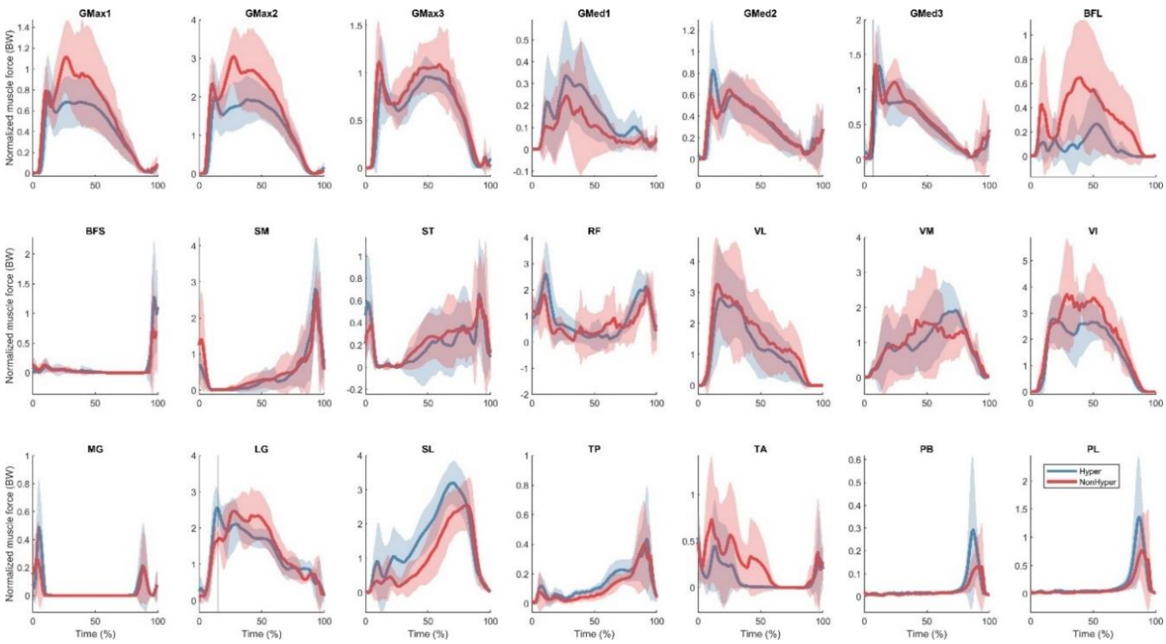

Figure 2: SPM analysis of calculated individual muscle forces for GJH and Controls during the ground contact phase of CUT task.

DISCUSSION: Individuals and athletes with GJH experience more frequent and more severe injuries to the knee (Decoster, 1999). However, the control strategies used by individuals with GJH to stabilize their joints are largely unknown. Evaluation of muscle activity with EMG is difficult during dynamic tasks, with many limitations in interpretation of that type of data due to movement artefact, muscle motion under the skin resulting in different areas of muscle under the electrode, and, with fast athletic manoeuvre's, the dynamic interaction of eccentric and concentric muscle activity resulting in delayed or changing neural drive to the muscle. In this investigation, an OpenSim-driven model was used with an optimisation routine to calculate the most likely muscle force contributions to the movements. Differences between GJH and control groups were then explored. The study was powered to detect only large effect sizes between groups, and did not detect any consistent muscle force differences between these groups. Most would hypothesize that individuals with GJH would use more muscle activity and forces to stabilize their hypermobile articulations, which is contrary to the current study findings. It is thus possible that the lack of any differences in muscle forces between groups may be a factor in the increased incidence of severe knee injuries in the GJH population.

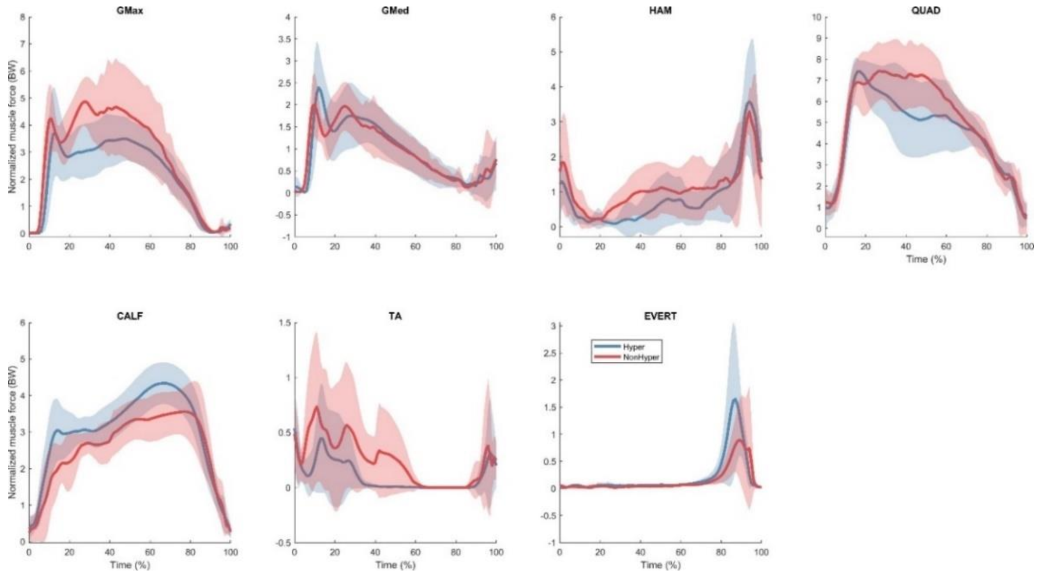

Figure 3: SPM analysis of calculated muscle group forces for GJH and Controls during the ground contact phase of CUT task.

CONCLUSION: This investigation compared model-derived individual muscle forces in the lower extremity during a single leg land and cut task between athletes with GJH and controls, and found no large differences between groups. These findings are unexpected given the greater need for joint stability in a lower extremity with greater generalized joint laxity.

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