Analyses of Isokinetic and Closed Chain Movements for Hamstring Reciprocal Coactivation

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Context: Researchers have postulated that coactivation of the hamstrings during active knee extension assists the anterior cruciate ligament in maintaining knee joint stability by exerting an opposing force to anterior tibial translation. Objective: To compare the reciprocal coactivation of the hamstrings while performing low and high velocity isokinetic movements and two closed chain movements. Design: Within subject’s comparison of isokinetic and closed chain exercises. Setting: Biomechanics laboratory utilizing a Cybex norm isokinetic dynamometer and Biopac Data Collection system. Participants: 12 healthy women. Main Outcome Measures: The root mean square of the Electromyogram (rmsEMG) was used as a measure of overall muscle activity. Results: The rmsEMG for hamstring coactivation during knee extension showed significant differences between the isokinetic movements and the closed chain exercises with greater coactivation when performing the isokinetic movements. In addition, greater activity was seen at the higher isokinetic velocity and during the one legged squat. Conclusions: These results suggest isokinetic movements, particularly at high speed, can more effectively increase the coactivation activity of the hamstrings when compared to two closed chain activities. Key Words: functional exercise, electromyogram, leg musculature

Researchers have investigated the effect of hamstring muscle force on knee joint stability both in vitro and in vivo. Of particular interest are those in vivo studies that have measured hamstring surface electromyography (SEMG) during knee-joint exercise. Based on these studies, researchers have postulated that coactivation (antagonist activity) of the hamstrings during active knee extension assists the anterior cruciate ligament (ACL) in maintaining joint stability by exerting an opposing force to anterior tibial translation. A lack of knee-joint stability often results in quadriceps muscle contractions creating unwanted stresses on internal joint structures, episodes of joint instability, and partial atrophy of the surrounding muscles. Recently, Croce et al and Miller et al examined hamstring coactivation patterns during varying velocity isokinetic movements. They noted that movement velocity impacted the coactivation activity of the biceps femoris (BF) and medial hamstrings.
Isokinetic dynamometry is often utilized to assess muscle function and is frequently a part of a rehabilitation protocol. A common rehabilitation and testing protocol utilizes both low and high-velocity movements, commonly termed Velocity Spectrum Exercise or Velocity Spectrum Testing (VST), using reciprocal movements (ie, extension immediately followed by flexion).\textsuperscript{15,16,17} With VST the individual moves at low and high velocities to assess muscle function under varying demands. In addition to isokinetic dynamometry, functional test such as leg squats and hops are also used to evaluate a patient’s readiness to return to full physical activity.\textsuperscript{18,19,20} The purpose of functional testing is to assess a patient’s performance while performing activities similar to competition demands.

As two distinct modalities are utilized in rehabilitation and assessment, it stands to reason that a comparison between the two techniques would be useful.\textsuperscript{19,21,22} English et al\textsuperscript{21} determined that a single leg hop was a good measure of leg strength comparable to an isokinetic assessment when body weight was factored. Wilk et al\textsuperscript{22} also found positive correlates between functional testing and isokinetic scores but only for the quadriceps with no correlation for hamstring scores. Lephart et al\textsuperscript{19} found that isokinetic assessment was a poor measure of an athlete’s functional capacity. All of these studies\textsuperscript{19,21,22} measured isokinetic parameters such as work and peak torque and functional parameters such as distance to perform the comparisons.

What has not been examined is a comparison of the actual muscle activity between isokinetic and functional activity, particularly as it relates to hamstring coactivation. Such a comparison could assist clinicians in determining which exercises or type of movement best utilize the hamstrings, therefore may minimize anterior knee translation. Accordingly, the purpose of this investigation was to compare hamstring coactivation during isokinetic, both high and low speed movements, to hamstring coactivation when performing two closed chain rehabilitative exercises.

**Methods**

**Experimental Design**

A within subjects repeated measures design was performed with 4 exercises (Isokinetic 100° s\textsuperscript{-1} and 400° s\textsuperscript{-1}) and two closed chain exercises (one legged squat and two legged squat) in which hamstring coactivation muscle activity was the measure of interest. Isokinetic speeds were chosen to represent both high and low speed movements as is typically done in an isokinetic assessment.

**Subjects**

The subjects were 12 healthy adult females (age = 22.7 ± 2.0 years, mean height = 161.1 ± 6.6 cm, mean weight = 63.5 ± 5.8 kg) with no known knee pathologies and familiarity with isokinetic testing and the prescribed closed chain exercises. The Institutional Review Board of the University of New Hampshire approved methods and procedures.
Instrumentation

**Electromyography.** Bipolar surface EMG was used to determine the electrical activity of the biceps femoris and the medial hamstrings (semimembranosus and semitendinosus) during the isokinetic movements and during the closed chain exercises. Silver/silver chloride surface electrodes were placed 2.5 cm apart and parallel to the muscle fibers over the longitudinal midline between the motor point and the tendon according to Warfel. A common reference electrode was placed over the head of the fibula. The skin was cleaned and abraded to achieve skin impedance of < 5 kΩ. The EMG signal was digitized on-line with a sampling frequency of 2000 Hz using the Biopac collection system processed through a Dell Optiplex computer with high and low pass filters of 20 and 400 Hz, respectively. The gain was set at 1000 with a common mode rejection ratio of 90 dB. The raw EMG signal was stored and the mean amplitude root mean square (rmsEMG) was calculated for the repetition in which the peak torque occurred for the tested isokinetic velocities. For the closed chain exercises, the repetition in which maximal muscle activity was observed was analyzed. Coactivation was measured as the hamstring activity during the knee extension phase of the activities. The rmsEMG was calculated as a percentage of a maximal voluntary contraction according to Knutson et al and used as a measure of muscular activity.

Dynamometer Set Up

Each subject was seated with her back fully supported in 75 to 80 degrees of hip flexion. Velcro straps were placed across the hips, waist, and chest with the lower tibia strapped into the pad on the arm of a Cybex Norm isokinetic dynamometer (Computer Sports Medicine, Inc.: Humac Norm Testing and Rehabilitation System Users Guide, Stoughton, MA, 2003). The lateral epicondyle of the knee was aligned with the axis of rotation of the dynamometer.

Test Protocol

Prior to data collection, subjects participated in stretching exercises for the quadriceps and the hamstrings for approximately 10 minutes and were tested at angular velocities of 100° s⁻¹ and 400° s⁻¹. Subjects were allowed 6 submaximal warm-up repetitions at each angular velocity to become familiar with procedures. They performed maximal effort contractions of the quadriceps (extension) followed by maximal effort flexion of the hamstrings for six continuous repetitions at the two test velocities. A 5-minute rest period was given between each test velocity to minimize the effect of fatigue. Order of velocities was counterbalanced over subjects. Subjects were instructed to push or pull as fast as possible using strong verbal encouragement (“push fast” or “pull fast”) during the test procedures.

Closed Chain Exercises

During both the one-leg and two-legged squats subjects were told to flex the leg to a count of one and return to the extended position to a count of one. As the actual
speed of movement could vary among subjects, we measured the actual speed by attaching an electrogoniometer (Biopac systems) to the lateral side of the leg on which the electrodes were placed and calculating the time and ROM. Using this system, it was determined that for both the one legged and two legged squat the subjects moved an average of 110° s⁻¹ with a high speed of 132° s⁻¹ and a low speed of 92° s⁻¹.

One-Legged Squat

The subject stood on the tested (balance) leg keeping the other leg off the floor: the shoulders flexed 90 degrees and their trunk straight with the eyes looking forward. By flexing the balance leg, the subjects lowered themselves till the thigh of the balance leg was parallel to the floor. The subject then stood upright by pressing the heel of the balance leg into the floor while keeping the trunk straight. Six repetitions were performed with the repetition in which the highest muscular activity was seen used for analyses.

Two-Legged Squat

The subject stood with both feet on the floor, shoulders flexed 90 degrees, trunk straight with the eyes looking forward. By flexing both legs, the subject lowered until the thighs were parallel to the floor. The subject then stood upright by pressing heels into the floor while keeping the trunk straight. Six repetitions were performed with the repetition in which the highest muscular activity was seen used for analyses.

Data Analysis

A repeated measures ANOVA was used to assess differences in the hamstrings rmsEMG trials. The conservative Greenhouse-Geisser adjustment factor was used to evaluate observed within-group F ratios. Post hoc comparisons consisted of planned mean contrasts for the four different exercises. The criterion level for significant difference was set at $P < 0.05$.

Results

The rmsEMG for hamstring coactivation during knee extension showed significant differences between the open chain isokinetic movements and the closed chain exercises ($F = 23.954, P < 0.0005$) with greater coactivation when performing the isokinetic movements (27% vs. 18% MVC; Figure 1). In addition differences were seen between 100° s⁻¹ and 400° s⁻¹ ($F = 8.375, P < 0.01$) with the greater activity seen at the higher velocity (30% vs. 24% MVC) and between the one- and two-legged squats ($F = 15.85, P < 0.005$) with greater coactivation during the one-legged squat (22% vs. 14% MVC).
Isokinetic vs. Closed Chain Exercises

Discussion

This study serves to contrast the motor unit recruitment of the hamstrings during isokinetic and closed chain activities. Specifically, this study suggests that hamstring coactivation is greater during isokinetic movements, increasing as velocity increases. This may indicate an increased recruitment of the motor units at the higher velocities.

The relationship between EMG and movement velocity has previously been examined. Hagood et al\textsuperscript{6} and Miller et al\textsuperscript{14} noted that antagonistic EMG activity of the hamstrings increased with velocity of movement demonstrating overall greater activity. Robertson et al examining agonistic activity and found a strong relationship between hamstring torque production and iEMG activity.\textsuperscript{28} Hagood et al\textsuperscript{6} and Miller et al\textsuperscript{14} examined antagonistic activity and the integrated EMG while we examined agonistic activity and the rmsEMG. The combined results shed light on the role of velocity on muscle activation. Specifically, those antagonistic muscles increase overall activity as velocity increases but torque decreases demonstrating increased muscular recruitment. This may be due to the antagonist muscles needing to “brake” the action of the agonistic group hence protecting the joint.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image1.png}
\caption{Mean and Standard Error of Measurement for the percent MVC Hamstring cocontraction activity for the open chain isokinetic exercises and the closed chain one- and two-legged squat.}
\end{figure}
Comparisons between functional and isokinetic assessments have been reported previously.\textsuperscript{19,21,22} Lephart et al\textsuperscript{19} determined that isokinetic parameters were a poor measure of an individual’s functional capacity, instead recommending a battery of functional test. English et al,\textsuperscript{21} however, found a more positive relationship between isokinetic and functional parameters when work performed and body weight were considered. Wilk et al\textsuperscript{22} noted a positive correlation between functional testing and isokinetic knee extension. The authors concluded that a combination of parameters should be used to assess a patient’s capacities.

The current study was unique in that we were not concerned with actual functional assessment or isokinetic scores but rather on the ability of the hamstrings control extension, suggestive of their ability to properly stabilized the knee. While hamstring coactivation is associated with the muscles ability to stabilize, it is not a direct measure of joint stability, however, and should not be misinterpreted as such. We found that the closed chain movements we examined did not result in as great a coactivation as the isokinetic movements (Figure 1). This can be due to many reasons such as speed of movement or load placed upon the muscles. In addition, as the closed chain exercises utilize the hamstrings across two joints (knee and hip), there may have been less hamstring activity due to assistance in hip extension by the gluteals.

This study was limited to young healthy females, therefore the results can be generalized only to that population. Also, we limited our functional assessment to two simple closed chain exercises and cannot apply these results to other functional movements. We chose to normalize hamstring coactivation as a percentage of a MVC as opposed to as a percentage of the antagonistic activity as done previously.\textsuperscript{25} This was done for consistency between the two modes of exercise, as it would have been impractical to establish an MVC for the closed chain activities.

References


