Effect of Ankle Position on EMG Activity and Peak Torque of the Knee Extensors and Flexors During Isokinetic Testing

John P. Miller, Kerriann Catlaw, and Robert Confessore

The purpose of this study was to examine the effect of ankle position on the electromyographic (EMG) activity, peak torque, and peak knee flexion to extension torque ratio during isokinetic testing of the knee. Twelve healthy female athletes performed six maximal knee extension and flexion repetitions with their dominant legs at 60 and 180°/s with the ankle in a plantar flexed position and again in a dorsiflexed position. Root mean square EMG (rmsEMG) activity was determined by placing bipolar surface electrodes on the quadriceps and the hamstrings. Ankle position had no effect on the rmsEMG activity of the quadriceps or the hamstrings at either 60 or 180°/s. Significant differences were noted for peak flexor torque at 60°/s ($p < .001$) and 180°/s ($p < .01$) and for peak torque flexor/extensor ratio ($p < .01$), with higher values observed with ankle dorsiflexion. This suggests that ankle position affects knee flexor torque and flexor/extensor ratio but not hamstring activity during isokinetic testing of the knee.

Strength measures are used to determine the severity of an injury, an individual’s progress in rehabilitation, or the ability to produce effective movement (3, 4, 9, 10). Isokinetic dynamometry is used because it is a reliable means of measuring strength (2, 12). Isokinetic scores are often reported as absolute values such as Newton-meters of torque, as ratios related to body weight, or as ratios related to muscle balance. A frequently used measure in evaluating the knee is the ratio of flexor to extensor peak torque, referred to as the hamstring/quadriceps or flexor/extensor torque ratio (8, 12). It is suggested that an imbalance of these muscle groups may predispose an individual to injuries resulting in instability of the knee, such as injuries where there is damage to the anterior cruciate ligament (ACL) (20).

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The validity of an isokinetic assessment depends upon isolation of the muscle or muscle groups being tested. The implications of invalid testing could be serious. This is particularly true of the hamstrings due to their role in knee joint stability. Rehabilitation for ACL injuries stresses strength development of the hamstrings to prevent anterior tibial translation (17, 19, 20). In addition, the hamstrings are frequently injured during sprinting and other high-speed activities (7, 21). Errors in hamstring strength assessment could result in inaccurate perceptions of muscle strength, placing the athlete at increased risk of injury.

The hamstrings are the major flexors of the knee (14). The gastrocnemius can function as a minor knee flexor when the ankle is dorsiflexed (stretched), though its contribution is diminished in the plantar flexed (shortened) position (14). The primary function of the gastrocnemius is as a plantar flexor during the push-off phase of gait (14, 23). Recently, we reported that knee flexor torque is increased when the ankle is in the dorsiflexed position during isokinetic testing (13). In that study, however, we did not measure hamstring or quadriceps activity and only presumed that EMG activity was unchanged.

Current isokinetic testing protocols for the knee do not stress ankle position, emphasizing only trunk and leg stabilization (15). We are not aware of any previous investigations on the effect of ankle position on both EMG activity and torque during an isokinetic knee assessment. Therefore, the purpose of this study was to determine if ankle position affects the electromyographic activity and torque production of the muscles surrounding the knee during isokinetic movements.

**Methods**

**Subjects**

Twelve female student-athletes (age 18–21) with no known knee pathologies volunteered to participate in the study (Table 1). Informed consent was obtained prior to participation. All subjects were familiar with isokinetic testing, having been subject to isokinetic assessment of the knee within the previous 2 months. The experimental protocol was approved by the University of New Hampshire Human Subjects Review Committee.

**Isokinetic Testing Protocol**

The study was conducted in the Biomechanics Laboratory at the University of New Hampshire. A Cybex II Isokinetic Dynamometer (Cybex, Ronkonkoma, NY) was used to measure the strength of the knee extensors and flexors of the dominant limb. Dynamometer calibration was performed prior to testing, with each testing session taking approximately 75 min.

Knee extension and flexion were tested with subjects seated and with stabilization straps placed around the chest, waist, and distal femur. The axis of the dynamometer was aligned with the axis of the knee, and the tibial pad was placed
proximal to the medial malleolus. Torque values were recorded in Newton-meters and were corrected for the effect of gravity using the Cybex II+ gravity correction protocol (5). The leg was moved to a position of full extension and the dynamometer was locked in that position. The subject was then told to relax the leg. The dynamometer was released and the leg was lowered at 12°/s. The amount of torque produced by the weight of the limb on the dynamometer was then recorded and automatically calculated into the isokinetic torque values (6).

Subjects were tested at angular velocities of 60 and 180°/s with the ankle plantar flexed and again with the ankle dorsiflexed. Testing order was counterbalanced for speed and ankle position. We instructed each subject to actively hold her ankle in the prescribed position, as opposed to externally stabilizing the ankle.

Immediately prior to data collection, the subjects were allowed 6–10 submaximal warm-up repetitions at each speed with the ankle in both the plantar flexed and dorsiflexed positions. The subjects then performed a maximal-effort contraction of the quadriceps followed by a maximal-effort contraction of the hamstrings for six continuous repetitions of extension and flexion of the knee. A 10-min rest period was given between each test velocity, and a 30-min rest period was given between each condition (plantar flexed or dorsiflexed) to minimize the effect of fatigue on torque production (16). Subjects were instructed to push or pull as fast as possible with strong verbal encouragement (“push fast” or “pull fast”) during both test procedures. Peak torque was the highest recorded value among the sampled repetitions.

### EMG

Bipolar surface electromyography (EMG) was used to determine electrical activity of the vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), and semimembranosus (SM) during the isokinetic test. Silver/silver chloride surface electrodes were placed as close as possible to the estimated motor endplates of the muscles according to the method of Warfel (22). The electrodes were 2.5 cm apart from center to center with a common reference electrode placed over the head of the fibula. The skin was cleansed and abraded to achieve skin impedance of <5 kΩ.

<table>
<thead>
<tr>
<th>Physical Characteristics of Subjects</th>
<th>M</th>
<th>SD</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>19.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.9</td>
<td>6.4</td>
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</table>
The EMG signal was digitized on-line with a sampling frequency of 1,024 samples \( \cdot \text{s}^{-1} \) using a data acquisition card (DAS-16 Metabyte) processed through a Gateway 2000 486DX/33 computer with high- and low-pass filters of 20 and 400 Hz, respectively. The gain was set at 1,000 with a common mode rejection ratio of 90 dB. Normalization to a maximal voluntary isometric contraction (MVIC) was done according to the recommendations of Knutson et al. (11) with the subject attached to the Cybex II\textsuperscript{+} isokinetic dynamometer and with the leg in 45° of flexion and the ankle in a neutral position. The normalized rmsEMG was used as a measure of muscular activity according to Basmajian and De Luca (1) and was calculated for extension and flexion in the repetition in which peak torque occurred.

**Data Analysis**

Normalized rmsEMG was analyzed by a \( 2 \times 2 \times 2 \) (Muscle Group x Ankle Position x Speed) repeated-measures ANOVA. Hamstring peak torque and quadriceps peak torque were also analyzed by a \( 2 \times 2 \times 2 \) (Muscle Group x Ankle Position x Speed) repeated-measures ANOVA, with a separate \( 2 \times 2 \) (Position x Speed) repeated-measures ANOVA used to determine differences in peak torque ratio. The small number of subjects precluded use of MANOVA for multivariate analysis of both torque and EMG measurements. The conservative Greenhouse–Geisser adjustment factor was used to evaluate observed within-group \( F \) ratios.

**Results and Discussion**

Ankle position had no influence on the EMG activity of the quadriceps or the hamstrings at either 60 or 180°/s (Figure 1). No differences were noted for extensor peak torque at either test velocity; however, significant differences were noted for peak flexor torque at both 60°/s \( (F = 21.2, p < .001) \) and 180°/s \( (F = 19.6, p < .01) \) (Table 2) and for the flexor/extensor ratio at both test speeds \( (F = 16.65, p < .01) \) (Table 3) with higher values observed when the ankle was dorsiflexed.

This study clarifies the effect of ankle position on EMG activity and torque production of the muscles surrounding the knee during an isokinetic assessment. Specifically, when the ankle is dorsiflexed, knee flexor torque is increased without an increase in hamstring activity.

The need for accurate assessment of hamstring strength cannot be overemphasized. The hamstrings flex and rotate the knee (14), and they prevent anterior translation of the tibia on the femur (19, 20). Shoemaker and Markolf (19) demonstrated that the hamstring muscle group could, if strong enough, resist disruption of the ACL. Solomonow et al. (20) determined that in subjects with ACL deficiency, the hamstrings could correct anterior subluxation of the tibia, particularly during maximal-effort knee extension. Therefore, strengthening of the hamstrings is a considerable component in ACL rehabilitation. Also, due to hamstring
function in controlling leg extension during sprint activities, the hamstrings are frequently injured among sprinters and jumpers (7). This makes standardized testing of the hamstrings necessary to minimize the possibility that an athlete will return to activity prematurely.

The role of hip and body position on isokinetic knee flexion has previously been examined (24, 25). Worrell et al. (25) demonstrated that when the subject is in the prone position with the hip extended, knee flexor torque is diminished when compared to the seated position. Worrell et al. (24) also noted that the peak flexor torque was greater in the prone versus the supine position. Our findings suggest that ankle positioning also affects the torque-producing capability of the knee flexors and therefore the flexor/extensor ratio without altering hamstring activity.

Robertson et al. found a strong relationship between torque production and EMG activity in the hamstrings (18). In Robertson’s study (18), EMG activity of the biceps femoris increased as flexion torque increased. We found increased flexor torque without increases in EMG activity in the hamstrings. The increased knee flexion torque seen in this study was apparently due to the contribution of the gastrocnemius when it was lengthened (i.e., when the ankle was dorsiflexed). This view is supported by a 12% decrease in knee flexion torque at 60 and 180°/s when the ankle was plantar flexed. Plantar flexion of the ankle results in active insuffi-
Table 2  Knee Extensor and Flexor Torque (in N•m) With the Ankle Plantar Flexed and Dorsiflexed at 60 and 180°/s

<table>
<thead>
<tr>
<th></th>
<th>Extension</th>
<th></th>
<th>Flexion</th>
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<tbody>
<tr>
<td></td>
<td>Plantar flexion</td>
<td>Dorsiflexion</td>
<td>Plantar flexion</td>
<td>Dorsiflexion</td>
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<td></td>
<td>M</td>
<td>SD</td>
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<td>SD</td>
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<tr>
<td>60°/s</td>
<td>149.9</td>
<td>20.3</td>
<td>152.6</td>
<td>26.1</td>
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<td>180°/s</td>
<td>74.1</td>
<td>11.3</td>
<td>73.1</td>
<td>8.8</td>
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</table>

*Significant differences between the plantar flexed and dorsiflexed position (p < .001).
**Significant differences between the plantar flexed and dorsiflexed position (p < .01).

Our method of maintaining ankle position warrants discussion. We had each subject voluntarily hold the ankle in either the plantar flexed or dorsiflexed position. Fixing the ankle either by taping or by other artificial means would have likely resulted in an even greater force of contraction from the gastrocnemius. The gastrocnemius would have a force to resist, effectively removing the open chain condition. Additionally, to increase the clinical relevancy of the study, we chose to replicate the isokinetic assessment technique commonly used in the clinic, which excludes the use of artificial stabilization of the ankle.

Conclusions

This study suggests that dorsiflexing the ankle increases knee flexor torque and the flexor/extensor ratio during open chain isokinetic exercise without increasing hamstring activity. This will produce an invalid isokinetic assessment of the knee.
if the goal of the test is to determine hamstring strength. If the clinician wants to accurately determine the strength of the hamstrings and the hamstring/quadriceps ratio, the ankle should be plantar flexed. This will place the gastrocnemius in an active insufficient position, diminishing its role as a knee flexor. However, ankle position does not affect hamstring muscle EMG activity and appears to play no role in hamstrings involvement in isokinetic knee flexion.

References