Measurement of Knee-Joint-Position Sense in Women With Genu Recurvatum

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Context: Proprioception of the knee joint.

Objective: To determine the difference in knee-joint-angle reproduction in women with and without genu recurvatum (GR).

Design: Between-subjects.

Setting: Clinic.

Subjects: Twenty-four women divided into 2 groups according to their standing knee-extension angle.

Main Outcome Measures: Each subject's ability to actively reproduce active positioning of 3 knee angles (10, 30, and 60°) was measured. Pearson correlation coefficients were calculated to determine correlation values for standing GR angle and absolute angular error (AAE). A 1-way repeated-measures MANOVA was computed to evaluate differences in group, angle, limb, and trial.

Results: Standing GR angle correlated significantly to the AAE angle at 10° (r = .48). The high-recurvatum group consistently scored worse, with the highest error rate occurring at 10°.

Conclusion: Individuals with GR might have diminished proprioceptive sense at end-range extension that could potentially lead to knee injury.

Key Words: genu recurvatum, ACL injury, proprioception


Several articles have been published over the last few years dealing with the increased incidence of knee injuries in female athletes. In this population, injury to the anterior cruciate ligament (ACL) is one of the most common and serious injuries. Several factors have been identified as related to the increased incidence, including ligament laxity, femoral notch size, limited muscle strength, muscle activation patterns, muscular fatigue, joint proprioception, hormonal changes, and lower extremity alignment. It is a combination of factors that probably causes these devastating injuries. This study investigates the relationship between 2 factors: sagittal-plane knee alignment and joint proprioception.

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Sagittal-Plane Knee Alignment

The tibiofemoral joint has the ability to move in all 3 cardinal planes. Normal standing knee position is 5–10° of valgus in the frontal plane and 0–5° of extension in the sagittal plane. Deviation of this normal position can cause excessive loading to various joint structures such as the menisci or ligaments. Genu recurvatum is a position of the tibiofemoral joint in which the range of motion is beyond the normal amount of 5° in the sagittal plane. Clinically, it appears that women, especially adolescent women, exhibit greater standing genu recurvatum than men do. Probable causes of genu recurvatum in standing include faulty habit, poor quadriceps strength, posterior capsule laxity, and poor knee-joint-position sense. With quadriceps muscle weakness, genu recurvatum provides greater knee stability by allowing the ground-reaction force to pass anteriorly to the knee joint.

Standing with the knees in hyperextension places excessive strain on ligaments and the posterior portion of the knee capsule. Besides the obvious stretch to the posterior ligaments, portions of the ACL are also placed in a position of stress in this habitual posture. Further stress from high-velocity, dynamic activities such as running, cutting, and jumping could create repeated forces on the ACL that could surpass the tensile capacity and elastic recovery limits of the ligament, resulting in disruption. Loudon et al found in women the 2 variables of genu recurvatum and hyperpronation to be associated with nonoperative ACL injuries.

To prevent faulty standing posture, one must develop a dynamic awareness of neutral joint position and be able to maintain this position in sporting activity. When the knee is flexed, the hamstrings are in a position to stabilize the tibia more efficiently and to prevent abnormal anterior translation.

Proprioception

The ability to sense joint position in space is a component of proprioception. Four types of joint receptors have been described by Freeman and Wyke. Types I, II, and III receptors are found in various layers of the joint capsule and ligaments and provide information about speed, acceleration, position, and direction of movement in the knee joint. Afferent feedback from these mechanoreceptors, along with receptors in the muscle and skin, returns to the central nervous system via cortical pathways. A keen sense of joint position provides dynamic joint stability in skilled movements via motor programming and muscle reflex.

Deficiencies in knee-joint-position sense can lead to biomechanically unsound limb position such as hyperextension of the joint. It could be hypothesized that individuals with genu recurvatum are more prone to injury because of their faulty joint-position sense. Impaired proprioception is cited as a major factor predisposing one to degenerative joint disease and ongoing
instability in the ACL-deficient knee. Individuals who present with faulty joint position such as genu recurvatum might evoke abnormal articular afferent information that decreases joint-position sense. A proprioceptive deficit can lead to alterations in joint stability and control of joint motion. The purpose of this study was to determine the difference in knee-joint angle reproduction in women with varying degrees of genu recurvatum.

Methods

Subjects

Twenty-four women between the ages of 20 and 32 years (mean age = 24 ± 3 years, height = 168.3 ± 5.1 cm, and weight = 60.4 ± 8.2 kg) were recruited for this study. Subjects were healthy, with no history of knee-joint ligamentous/cartilaginous injury to either lower extremity as self-reported on a knee-injury questionnaire. All subjects were graduate students who participated in various exercise activities at least 3 times a week. Bilateral lower extremity measures were taken, resulting in 48 knees tested. Subjects were assigned to 2 groups based on standing knee-extension range. Those with standing knee extension ≥5° were assigned to the high-recurvatum group (group I), and those with knee extension <5° were assigned to the low-recurvatum group (group II). The university medical center’s institutional review board approved the study, and each subject signed a statement of informed consent before participation.

Procedure

Subjects were instructed to stand in their normal stance with weight equally distributed between their legs. Knee extension was measured by standard goniometric procedure (Figure 1). Each subject was then positioned on a BodyMaster® leg-press machine (weight set at 30% of subject’s body weight) so that her knee-flexion angle was 90° in the start position. Proprioception can be measured clinically by either the threshold of the detection of passive movement or the ability to reproduce passive positioning. Most of the cited studies used a non-weight-bearing position. This study investigated weight-bearing knee-joint reproduction in individuals with standing genu recurvatum. Even though this weight-bearing position involves contribution from the hip and ankle joints, it mimics a more functional movement than non-weight-bearing knee extension does. Taylor et al investigated knee-position error detection in closed and open kinetic chain tasks and found no significant difference between the 2 positions.

Two inclinometers were placed on each subject’s lower extremity, one on the femur and a second on the tibia to provide recording of knee-joint angle in the sagittal plane (Figure 2). The subject was blindfolded. For active reproduction of active positioning (ARAP), the subject was asked to extend the leg with guidance to 1 of the 3 predetermined angles (10, 30, and
60° in random fashion. The angle was held with the test leg for 15 seconds, and the subject was instructed to concentrate on this position. The subject’s leg was then returned to the starting position. The subject was then asked to reproduce the target angle and hold for 10 seconds while this angle was recorded as a trial. Three trials were recorded at each target angle. The subject rested for 30 seconds and then performed 3 trials at the other 2 knee angles.
The entire procedure was then performed on the other extremity. Reliability of the testing inclinometers to measure knee-joint angle was determined before the undertaking of this study, resulting in a correlation coefficient of \( r = .96 \).

**Data Analysis**

Mean and standard deviation were calculated for genu recurvatum angle for each group. Absolute angular error (AAE) was operationally defined as the absolute difference between the target angle and the perceived angle. AAE was calculated for each of the 3 trials for the 3 target angles for each limb of each subject. Data were organized using Microsoft Excel (1996) into group (high-recurvatum or low-recurvatum), limb (right or left), angle (10, 30, or 60°), and trial (1, 2, or 3).

**Statistical Analysis**

Statistical analysis was conducted using the SPSS computer software system (SPSS Inc, Chicago, Ill). The following statistical tests were applied to the data. First, genu recurvatum angle for all subjects was correlated to mean trial AAE for each of the 3 target angles using Pearson correlation coefficients. Significance level was set at \( P < .05 \). Next, a 1-way repeated-measures MANOVA was computed to evaluate differences in group, angle, trial, and limb. Significance level was \( P < .05 \).

**Results**

**Correlations**

Standing knee angle positively correlated significantly with the target angle of 10°, with a correlation value of .478 (\( P < .001 \)). The correlation value at 30° was .281 (\( P = .053 \)) and at 60° was .217 (\( P = .138 \)).

**MANOVA**

Group 1 had a mean knee angle of 8.3°, with a standard deviation of 2.2°. Group 1's AAE at 10° was 7.8°, with a SEM of 0.96. The group's AAE at 30° was 6.3° (SEM = 0.75) and at 60° was 5.6° (SEM = 0.66). The 10° AAE was significantly higher than the 60° AAE (\( P = .014 \)), but not compared with the 30° AAE (\( P = .073 \)). Group 2 had a mean knee angle of 2.6°, with a standard deviation of 2.4°. This value was significantly different than the standing knee angle of group 1 (\( P < .0001 \)). Group 2's AAE at 10° was 5.0° (SEM = 0.57), at 30° was 5.4° (SEM = 0.69), and at 60° was 4.5° (SEM = 0.62). The AAE was not significantly different between target angles. The AAE was significantly different between group 1 and group 2 at all target angles (\( P < .0001 \)). Figure 3 depicts the group differences at the 3 target angles.
Table 1 lists the AAE data for both limbs of both groups at each angle. There was no significant difference between limbs within a subject.

As a single group, subjects scored significantly worse at 10° (AAE = 6.6°, SEM = 0.59) than at 30° (AAE = 6.0°, SEM = 0.52) or 60° (AAE = 5.0°, SEM = 0.52). Trial differences are displayed in Figure 4. For the 10° reproduction angle, trial AAEs are as follows: trial 1, 6.4° (SEM = 0.66); trial 2, 6.7° (SEM = 0.56); and trial 3, 6.9° (SEM = 0.65). For the 30° reproduction angle, trial AAEs are as follows: trial 1, 5.4° (SEM = 0.65); trial 2, 6.1° (SEM = 0.53); and trial 3,

![Figure 3](image)

Figure 3 Absolute angular error for high-recurvatum and low-recurvatum groups at 3 angles. Black box = group 1 (high recurvatum); hatched box = group 2 (low recurvatum).

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<th>Table 1 Absolute Angular Error Between Group, Limb, and Angle</th>
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*Group 1 = high-recurvatum group.
†Range of hyperextension.
‡Group 2 = low-recurvatum group.
Mean absolute angular error over 3 trials at 3 angles.

6.6° (SEM = 0.55). For the 60° reproduction angle, trial AAEs are as follows: trial 1, 4.3° (SEM = 0.46); trial 2, 5.3° (SEM = 0.48); and trial 3, 5.5° (SEM = 0.56). The difference between trial AAEs is significant for the 30° angle for trials 1 and 3 ($P = .000$) and trials 2 and 3 ($P = .017$). At 60° there was significant trial difference between trials 1 and 2 ($P = .002$) and trials 1 and 3 ($P = .007$). There was no significant difference between trials at the 10° angle.

**Discussion**

Studies using animal models have shown that the joint capsule receptors act as end-range detectors. An increase in joint capsule laxity secondary to habitual posture results in a subsequent reduction of afferent activity that might contribute to impaired joint-position sense. Therefore, a predisposing factor to knee injury in the female could be a loss of proprioceptive sense near 0° knee flexion, especially in individuals who habitually stand in genu recurvatum. This study was designed to answer the following questions: (1) Does the amount of genu recurvatum correlate with ARAP? (2) Does ARAP error vary depending on the knee-joint angle? (3) Is there a difference in limb AAE within individuals? (4) Is there a difference in AAE between trials?

The results of the Pearson correlation coefficient analyses demonstrated a moderate correlation between standing knee angle and AAE. This correlation was significant at the 10° knee angle. These results indicate that as standing genu recurvatum increases in women, the error associated with ARAP also increases. Furthermore, this association is most pronounced near full extension. As suspected, when the subjects were divided into high-recurvatum and low-recurvatum groups, a significantly greater AAE was
found in the high-recurvatum group at all 3 target angles. Past studies have looked at hypermobile individuals and proprioception as measured by time to detect passive movement (TTDPM). A study by Hall et al found hypermobile individuals to have increased TTDPM in the knee joint. No other studies have investigated weight-bearing knee ARAP.

The greatest amount of AAE was found at the target angle of 10° for the high-recurvatum group. Interestingly, this did not hold for the low-recurvatum group, whose highest AAE was at the 30° angle and was not significantly different than the 10 or 60° AAEs. In the high-recurvatum group, lack of tension in the posterior knee-joint capsule might reduce the ability of an individual to detect neutral position of the knee joint. Hall et al found that nonhypermobile subjects had increased acuity in TTDPM toward full extension that was not present in the matched hypermobile subjects.

There was no significant difference in within-subject limb ARAP error in either of the 2 groups. In this study, limbs were merely divided into right and left. For the high-recurvatum group, the left limb consistently scored a higher AAE. If leg dominance had been assessed, perhaps a significant difference would have been found.

Absolute angular error between trials increasingly progressed from trial 1 to trial 3 at all 3 target angles. This trial difference was significant for various combinations at the 30 and 60° target angles. One possible explanation for an increase in AAE as trials progress is a decline in motor memory. Taylor et al found that joint reproduction declined between trials with the introduction of a cognitive distraction. A second possible cause of deterioration from trial to trial is muscular fatigue. Rozzi et al demonstrated that athletes exhibited a decline in TTDPM into extension with the introduction of muscular fatigue. Why there was no significant difference between trials at the 10° angle might be related to a ceiling effect of the AAE.

**Conclusion**

This study has demonstrated that women with a high amount of genu recurvatum score worse on angular reproduction of knee-joint position. This error was greater at the 10° knee-flexion angle than at 30 or 60° of knee flexion. Within subjects, there was no difference between right and left AAE. Subjects had a tendency to score progressively worse from trial to trial at the same target angle.

**Clinical Implications**

The 3 major causes of noncontact ACL injuries are (1) planting and cutting, (2) straight-knee landing, and (3) 1-step stop landing with hyperextension of the knee. Because 2 of the 3 mechanisms involve hyperextension of
the knee, it can be hypothesized that women with postural hyperextension are at greater risk for knee injury. A habitual position of genu recurvatum might result from poor quadriceps control, as well as diminished knee-joint-position sense. Also, the hamstring is less efficient at 5° of hyperextension than at 30° of knee flexion. 17

Therefore, preventive and rehabilitative knee exercises should focus on proper lower extremity alignment through proprioceptive training. 38-40

References


Knee-Joint-Position Sense


