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Axial Rotation of the Knee in Women

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Eighty-five women with normal left knees were measured to determine the active axial rotation that is normally present at the tibiofemoral joint. Subjects were seated with the leg perpendicular to a measuring platform placed at floor level and rotation was measured with the knee flexed at 70, 90, and 110°. Mean total rotation was found to increase from 35 to 40 to 44° as the knee flexion angle increased ($P < 0.01$). External rotation from the neutral position at all angles of flexion was approximately twice that of internal rotation. These values are in general agreement with those obtained in earlier studies, but are different from values given in many textbooks. Although precise measurement of axial rotation is difficult in a clinical setting, an approximation of symmetrical rotation can be made.

Normal function of the knee joint in flexion requires axial rotation of the tibiofemoral joint, and assessment of this rotation is an important part of the physical examination of the knee joint.[12] What constitutes a normal range of motion, however, is controversial. Little information is available and standard goniometric reference sources do not describe either a method for measurement or the normal range of motion.[5,14,15,21] Textbooks do describe axial rotation when the knee is in flexion, but disagree considerably about what constitutes the normal range of motion. "Normal" is given from 20 to 90°.[6,7,11,12,18,19,23,27–29]

Passive rotation of the knee in men was measured by Ross in 1932.[24] At 45° of flexion, rotation was found to be 41°, at 90°, it was 37°, and at 135°, it was 39°. Ouellet et al[22] studied passive knee rotation by means of roentgenograms taken in the sitting position and found rotation to be 40° in the right and 43° in the left.

Although most authors state that external rotation is greater than internal rotation,[2–4,8,18,19,26] some believe that internal is greater,[6,28] or that the two are equal.[12] Ross[24] found that external rotation was greatest at a knee angle of 45°, internal rotation was greatest at 135°, and at a knee-flexion angle of 90° he found no significant difference between internal and external rotation.

Values for active axial rotation are not available in the literature. Therefore, the purpose of this investigation was to measure active internal and external rotation of the knee at 70, 90, and 110° of knee flexion.

METHOD

The sample consisted of eighty-five women students, faculty members, and visitors at the Houston campus of Texas Woman's University (Table 1). The left knee of each subject was measured. Subjects with pathological conditions of the knee were excluded from the study.

The subjects were measured in three different sitting positions that were produced by sitting on a laboratory stool, a classroom chair, and a footstool (Fig. 1). Active internal and external rotation of the left tibia on the femur was measured at 70, 90, and 110° of knee flexion. Fine adjustments of the knee angles were made by placing wooden blocks underneath either the legs of the stool, chair, or measuring platform. The angle of knee flexion was measured by a long-arm universal goniometer.

The foot was secured to a footplate with padded straps that were attached to the medial edge of the plate (Fig. 2). The knee was rotated around the pivot hole in the heel area. The footplate rested on a pivot at the axis of a protractor that was attached to the measuring platform (Fig. 3). The degree increments of the protractor were projected 15 centimeters from the axis of motion.

The rotational indicator (Fig. 2) that was used

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TABLE 1
Age, height, and weight of subjects

	Age (years)	Height (cm)	Weight (kg)
Mean	24	165	58
Standard deviation	4.3	6.9	10.2
Range	19–44	152–180	42–109

Fig. 1. *Subject seated in a classroom chair with measuring apparatus in place. The knee is in 90° of flexion and neutral rotation.*

was made of orthotic splint material molded to fit an average left medial malleolus and distal end of the medial surface of the tibia. An adjustable cuff and belt around the distal portion of the thigh, were used to stabilize the hip joint (Fig. 1). Two lengths of wood that were hinged by a bolt and wing nut (Fig. 3), were used to identify the neutral position of the foot during positioning changes of the leg.

Subjects were measured with the left tibia and fibula perpendicular to the floor and the measuring platform. The horizontal axis of the left knee was maintained in the frontal plane. The foot of each subject was positioned on the footplate. To facilitate the placement of the tibia over the pivot, the center of the medial malleolus was marked with a pen and placed over the intersection of the two lines on the surface of the footplate. The rotational indicator was positioned around the malleolus with the superior, flat end placed against the shin. The indicator was secured tightly to the leg and the pointer was adjusted to lie superior to the degree markings but not touching the platform.

The investigator grasped the distal portion of the thigh and suspended the relaxed leg and foot

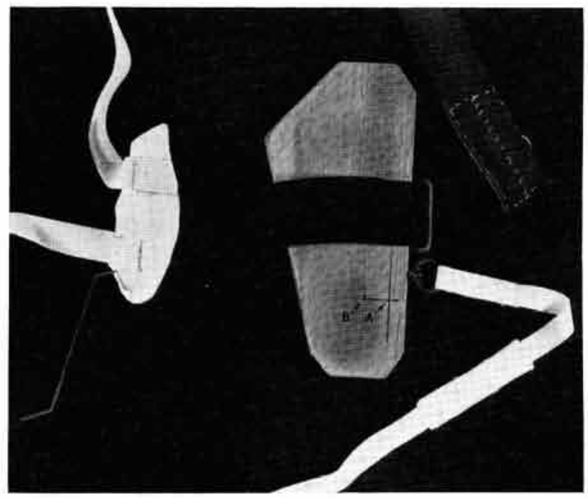

Fig. 2. *Footplate and rotational indicator. The footplate was designed with point A 2 centimeters medial from the pivot (point B). Point A marks the point over which the center of the medial malleolus was projected for alignment. The rotational indicator was made of orthotic splint material and a 16-gauge wire that was 25 centimeters long.*

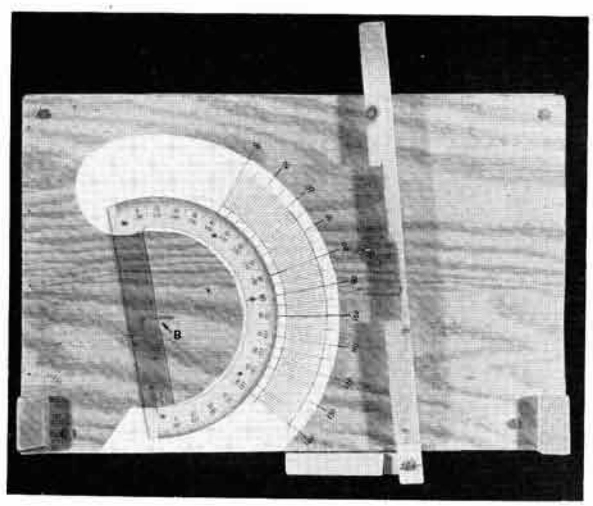

Fig. 3. *Measuring platform and neutral position marker. Point B indicates pivot screw around which axial rotation takes place. To the right is the neutral position marker used during positioning changes of the leg and foot.*

in space. The leg was lowered until the foot came to rest squarely on the measuring platform. The shorter length of the neutral position marker was placed against the lower border of the measuring platform, and the longer length was moved against the medial edge of the footplate. This angle was maintained by tightening the wing nut. The leg was then raised again, the pivot on the platform was placed underneath the footplate, and the leg was lowered onto it. The neutral position marker was placed against the lower border of the platform, and the leg and foot were rotated to the neutral position. The femur was placed against the cuff and the belt was tightened around the thigh proximal to the epicondyles.

For the first subject, the initial rotary measurements were made at a 90° angle of knee flexion; the 90° angle was randomly chosen. Subsequent measurements of the first subject followed at 110° and then 70°. Measurements of following subjects began at the knee angle last measured for the preceding subject and continued in the same order.

All subjects performed two practice trials of active internal and external rotations of the knee to familiarize themselves with the measuring device and the procedure. The foot was kept flat on the plate and care was taken to avoid inversion and eversion during the rotary movement. Subtalar and transverse tarsal movements were detected by movements of the tip of the wire indicator toward or away from the pivotal point. With pure rotational movement, the tip followed an arc that was congruent with the arcs on the surface of the measuring platform.

The neutral position of knee rotation was recorded. The subject performed active movements of internal and external rotation to the end of the range of motion twice; the angle of each movement was recorded to the nearest degree. Rotation was measured in the same way for each angle of knee flexion.

The average values of the two rotational movements in each direction were added to determine the total rotation. A one-factor analysis of variance, with repeated measures, was used to test for differences between the three angles of knee flexion (for internal, external, and total rotation). Scheffe's test was used to make post hoc comparisons. A correlated-samples *t* test was used to test for differences between internal and external rotation at each knee angle. All statistical procedures were carried out at the 0.01 level of significance.

TABLE 2

Rotation of the knee at three angles of knee flexion

Rotational movement and flexion angle (degree)	Mean* (degree)	Standard deviation (degree)	Range (degree)
Total range			
70	34.9	7.3	18–55
90	40.4	8.3	20–67
110	44.1	8.7	24–67
External			
70	25.3	5.5	11–42
90	27.8	5.5	14–43
110	29.4	5.4	15–43
Internal			
70	9.6	4.3	3–19
90	12.6	5.2	2–28
110	14.7	6.8	1–36

* Statistically significant differences ($P < .01$) were found for total, internal, and external rotation at each angle of knee flexion, and internal versus external rotation at each angle of flexion.

RESULTS

The mean for the total amount of axial rotation of the knee increased from 35 to 44° as the angle of knee flexion increased (Table 2). The smallest total range of rotation recorded at 90° of knee flexion was 20°; the largest was 67°. Mean values for external rotation increased from 25 to 29° as the angle of knee flexion increased and were approximately twice as great as those for internal rotation. Values of internal rotation and external rotation at the same knee angle were significantly different ($P < 0.01$). The three means for total rotation, as well as the three means for internal and external rotation, differed significantly at the 0.01 level. Post hoc comparisons showed a significant difference between each of the three means for internal, external, and total rotation ($P < 0.01$).

DISCUSSION

In this study, the value of 40° (SD = 8) for total axial rotation at a knee-flexion angle of 90° was similar to that found by other investigators who performed passive movement studies. Ross[24] found 37° (SD = 6.8) and Meyer found 42°.[20] Ouellet et al[22] who measured rotation on roentgenograms, found 40° on the right leg and 43° on the left leg. A comparison of these studies requires that differences in the methods of measurement, the type of motion measured, and the sex of the subjects be considered. Passive motion will most likely yield larger values than active motion, and all values will vary with the amount

of force applied. Nevertheless, the similar mean values do indicate that, within one standard deviation, the expected normal range of active axial rotation at 90° of knee flexion in women falls between 32 and 48°. Many of the average values stated in textbooks, therefore, are too low (20°) or too high (60, 75, or 90°).

The amount of the contribution made by internal and external rotation to the total range of motion is controversial. Ross[24] found no significant difference between the two motions when the knee was flexed 90°. At 45° of flexion, he found external rotation to be greater, and at 135° of flexion he found internal rotation to be greater. In this study, external rotation was found to be approximately twice that of internal rotation at all of the knee-flexion angles that were measured. This finding supports claims that external rotation contributes more to the total movement than internal rotation.[2-4, 8, 18, 19, 26]

Discrepancies among results could be caused by the differences in definition of the neutral position of the leg and foot that was used. In this study, the dependent foot was placed on the measuring platform at the natural angle of tibial torsion, with the leg perpendicular to the platform and floor; this position was designated as neutral (0° of axial rotation). Inman[13] states, however, that the mean angle for "external tibial torsion" in adults is 23° with extremes of 30° in each direction. Because of this variability, therefore, different foot placement or the use of different landmarks will cause variation in the values obtained for internal and external rotation.

Authors disagree about which angle of knee flexion allows the greatest rotation. Many feel that it is 90° of flexion,[1, 2, 9, 17, 19, 23, 26, 28] but this belief is not supported by the experimental evidence. Ross[24] found that the minimum amount of axial rotation occurred at a knee angle of 90°, and the maximum rotation occurred at an angle of 45°. Meyer[20] found that total knee rotation increased proportionately as the angle of knee flexion increased. This study found that axial rotation increased significantly as the knee-flexion angle increased, thus supporting the statement of Meyer[20] and others[6, 7, 10] that flexing the knee beyond 90° produces greater ligamentous laxity and greater rotation. This claim is also supported by the fact that both internal and external rotation increased proportionately as the angle of knee flexion increased.

The measurement of active axial rotation was difficult, since movements at the hip, ankle, and foot occur naturally during rotation. The hip could be immobilized easily, but movements of the ankle and foot were more difficult to prevent. Efforts to reduce such movements by using straps, and by a conscious effort of the subject to avoid ankle movements, produced adequate results, but it was impossible to stop the movements completely. Certain indicators in this method enabled the investigator to detect unwanted movements of the foot and ankle. When the foot remained in a neutral position, neither inverted nor everted, the wire indicator that was attached to the medial malleolus would describe an arc in which each point would be an equal distance away from the axis of rotation. However, if the foot and ankle were inverted during internal rotation of the knee, the tip of the indicator would move toward the center of rotation; if they were everted, the tip would move away from the center. The investigator could detect these movements during the practice trials and instruct the subject to try to prevent the unwanted movement. Some subjects commented that they found that an increase in downward pressure on the foot plate helped to decrease the movements.

Another area of difficulty was the placement of the rotational axis of the tibia over the pivotal point. Because information on the location of the longitudinal axis at the distal end of the tibia was not available, it was estimated by examining tibial roentgenograms, photographs, and bone samples. The position of the axis of rotation on the tibial plateau was observed. Then a line was extended from the medial intercondylar tubercle[16, 17, 25] distally, and the approximate position was measured from the medial edge of the medial malleolus. Two centimeters was used as the estimate of this distance from the pivotal point.

Although precise measurement of axial rotation is difficult in most clinical settings, an approximation of symmetrical rotation can be performed easily and compared with that of the normal side. With the patient in a sitting position and leg dependent, the examiner can rotate the relaxed leg and watch the movement of the foot. Active rotation cannot be appraised in this way because concomitant movements of the subtalar and transverse tarsal joints will occur. Palpation of one of the bony prominences on the tibia is necessary to assess active rotation. The rotatory movement is most easily detected by palpating the head of the fibula or the lateral tibial tubercle (Gerdy's tubercle) where the iliotibial tract inserts. Since these points lie the greatest distance from the axis of rotation, they would describe the

largest arcs. The movement of these structures relative to the lateral condyle of the femur is thus easily determined.

More precise information on axial rotation would have to be obtained by a method that is similar to the one described in this study. Since rotation of the knee is directly related to the status of the cruciate, collateral, and capsular ligaments, this information could be important to the clinicians and patients during knee examinations and in a program of knee rehabilitation.

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