Gait Adaptations by Patients Who Have a Deficient Anterior Cruciate Ligament*

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ABSTRACT: **Sixteen patients who had unilateral deficiency of the anterior cruciate ligament and ten healthy control subjects were analyzed during level walking, jogging, and ascending and descending stairs. Kinematic and kinetic findings for the right and left hips, knees, and ankles of all of the patients and control subjects were recorded during each activity. Substantial differences from normal function were observed for both limbs of the patients during level walking and during jogging. The magnitude of the maximum moment that tended to flex the knee was reduced the most (140 per cent) during level walking. It was reduced less (30 per cent) during jogging, it was not changed while the patient descended stairs, and it was slightly increased while he or she ascended stairs.**

The reduction in the magnitude of the flexion moment about the knee was interpreted as the patient's effort to reduce or avoid contraction of the quadriceps. Reduction of the flexion moment reduces any contraction of the quadriceps because there must be a mechanical balance between the external moment (due to body weight and the weight and inertia of the segment of the limb) that tends to flex the knee and an internal moment (generated by contraction of the quadriceps) that tends to extend the knee. This so-called quadriceps-avoidance gait was related to the angle of flexion of the knee when the maximum flexion moment occurred during each activity. This angle of flexion was 20 degrees during walking, 40 degrees during jogging, and approximately 60 degrees during stair-climbing. We think that this correlation between the quadriceps-avoidance gait and the angle of flexion of the knee meant that the patients altered their gait to avoid the anterior displacement of the proximal end of the tibia that is normally produced when the quadriceps contracts while the knee is in nearly full extension. In this study, 75 per cent of the patients had a quadriceps-avoidance gait.

CLINICAL RELEVANCE: **The findings in this study indicate that when the anterior cruciate ligament is deficient, even the low-stress activity of walking on a level surface may be performed in an abnormal manner. This abnormal function could have long-term implications related to the changes that sometimes develop in knees in which a ruptured anterior cruciate ligament was never repaired or reconstructed.**

The changes in the function of the lower extremity that occur after injury to the anterior cruciate ligament are not well understood. This type of information is needed for optimum management of patients who have deficiency of the anterior cruciate ligament. Noyes et al.[10,11] found that approximately one-third of patients who had an anterior cruciate-deficient knee compensated enough to pursue recreational activities, another third compensated but had to discontinue many activities, and one-third had poor function. Whether the management of an anterior cruciate-deficient knee should be operative or non-operative remains controversial.

Noyes et al. carried out a long-term follow-up study of young, active patients who had chronic anterior-cruciate insufficiency that either had been previously undiagnosed or had been operated on unsuccessfully[10]. They reported a 44 per cent prevalence of both degenerative changes and moderate or severe symptoms during activities of daily living. On the basis of these observations, many surgeons have recommended operative repair and reconstruction to young patients who wish to remain active in sports that involve running and cutting (a side-step maneuver to make a 90-degree change in direction).

The variable natural history and the progression of degenerative disease in some patients but not in others who have similar injuries suggest that some patients who have cruciate deficiency make functional adaptations. To our knowledge, the nature of these adaptations during activities of daily living has not been evaluated.

Functional adaptations were demonstrated while patients who had anterior cruciate insufficiency performed a side-step cutting maneuver[2]. The adaptation consisted of more-than-normal flexion of the hip and knee during the part of the cutting cycle when high loads are transmitted across the knee joint. When the knee is flexed more, the hamstrings are in a position to stabilize the tibia more efficiently and to prevent abnormal anterior translation and

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internal or external rotation of the tibia at the knee. This apparent compensatory maneuver increases moments that tend to flex both the hip and the knee and necessitates additional activity of the quadriceps to maintain stability. Thus, adaptations in function of the knee to compensate for anterior cruciate deficiency seem to be accomplished by muscular forces that stabilize the knee during strenuous activities.

It is also possible that changes in function occur during the less strenuous activities of daily living. When a knee is flexed between 0 and approximately 45 degrees, any contraction of the quadriceps tends to displace the proximal end of the tibia anteriorly, thereby producing strain in the anterior cruciate ligament[4,5,7,12]. In the absence of function of the anterior cruciate ligament, a patient might, therefore, subconsciously avoid contracting the quadriceps to avoid displacing the tibia anteriorly during activities such as walking, jogging, or ascending and descending stairs. The extent of this effect depends on both the force of contraction of the quadriceps and the amount of flexion of the knee. At present, very little is known about the function of the knee during the activities of daily living in patients who have a deficient anterior cruciate ligament.

The goal of this study was a better understanding of the changes in function of the knee that occur while patients who have a deficient anterior cruciate ligament in one knee walk, jog, and ascend and descend stairs.

Materials and Methods

Sixteen patients who had unilateral anterior-cruciate deficiency were selected for study on the basis of arthroscopic or operative data that had been obtained at the time of reconstruction of the anterior cruciate ligament. Before treatment of the complete rupture, gait studies had been performed. Of the sixteen patients, five had had an isolated tear of the anterior cruciate ligament and eleven had had, in addition, a minor meniscal lesion. Six of the eleven lesions were in the medial meniscus; two, in the lateral meniscus; and three, in both menisci. Not more than 25 per cent of any torn meniscus had been removed. No other ligaments were injured, as determined by examination under anesthesia at the time of reconstruction.

The study population consisted of fourteen men and two women. The mean age was 26 ± 9.5 years; the mean height, 1.75 ± 0.15 meters; and the mean weight, 80 ± 10.1 kilograms. Each patient was examined clinically with the pivot-shift and Lachman tests, as well as with the posterior drawer test and medial and lateral laxity tests with the knee flexed 30 degrees (Table I). These clinical tests were not used to select the patients for the study, but rather to provide additional documentation of the arthroscopic or operative findings at the time of reconstruction.

There was no significant difference between the mean circumferences of the thighs on the injured and uninjured sides ($p > 0.05$). The alignment of the knees, which was measured while the patient stood, averaged 4 degrees of valgus angulation, and there was no significant difference between the normal and injured knees. No patient had pain in the knee or another musculoskeletal disorder.

TABLE I

MEAN SCORES FOR LAXITY IN SIXTEEN PATIENTS WHO HAD AN ANTERIOR CRUCIATE-DEFICIENT KNEE

Test*	Grade†	
	Mean	Standard Deviation
Lachman	1.6	1.0
Anterior drawer	1.4	0.6
Posterior drawer	0	0
Pivot shift	2.5	1.9
Medial laxity at 30 degrees of flexion	0.8	0.7
Lateral laxity at 30 degrees of flexion	0.4	0.7

* The patients were selected on the basis of an operative finding of a complete rupture of the anterior cruciate ligament. The clinical findings were not used in the selection process. In the control subjects, the results of all of the tests were negative.

† The findings were graded 0 to 4+, with 0 being normal and 4+ indicating the most laxity.

A control group of five healthy men and five healthy women was selected on the basis of age, height, and weight. The mean age of these normal subjects was 26 ± 5 years; the mean height, 1.67 ± 0.20 meters; and the mean weight, 62 ± 12 kilograms. No operation had been done on any joint in the lower extremities of the control subjects, and no control subject had any deformity or neuromuscular disorder that might impair normal walking. All clinical tests for stability of the knee were normal.

In the gait laboratory, the patients and the control subjects were tested with identical protocols during walking, jogging, and ascending and descending stairs. The walking and jogging were done on a ten-meter walkway. Data were collected during the middle stride of several strides, with the measurements starting just before the foot reached the force-plate. After this stride, each subject could then take several strides of deceleration after the foot of the limb that was being tested had lifted off the force-plate.

The subjects ascended and descended the stairs of a staircase that has been described previously[3]. The measurements were made while the subjects stepped onto the bottom step, which rested on the force-plate. Data were collected for the affected and normal lower limbs of the patients who had a deficient anterior cruciate ligament and for both lower limbs of the control subjects.

The instrumentation, which has been described previously[1], included a two-camera optoelectronic digitizer, light-emitting diodes, a multicomponent force-plate, and a minicomputer. Placement of light-emitting diodes on the test subjects, determination of the geometric centers of the joint, and recording of the kinetic data for the hip, knee, and ankle were done as previously described[1]. About each joint, external moments were calculated with the ground-reaction force and the weight and inertia of the segment of the limb[1]. The external moments about the three joints were converted into vector components aligned along the axes of