Introduction:
Early passive range of motion exercises are advocated following Achilles tendon repair. The goal of early mobilization is to promote tendon healing and avoid motion loss. However, the magnitude of the force transmitted through the Achilles during passive range of motion (ROM) is not known. Furthermore the degree to which Achilles forces can be decreased by knee flexion during passive ROM exercises has not been examined previously. Therefore, the purpose of this study was to determine the effect of knee flexion angle on Achilles tendon force during passive ankle dorsiflexion.

Methods:
The effect of knee flexion on Achilles tendon forces was examined in cadaveric testing and in vivo testing.

Cadaveric Testing: A total of seven lower extremities were used for cadaveric testing. A calcaneal osteotomy was made to provide a bone block with the Achilles tendon insertion intact. The calcaneal bone block was maintained in anatomic position by attaching it to a force transducer fixed to the superior surface of the remaining intact calcaneus. An electromyometer was attached to the ankle. The proximal femur was clamped and the knee joint was set at each of three knee flexion angles (0°, 45° or 90°) using a standard goniometer. At each knee flexion angle the foot was manually cycled from full plantarflexion to full dorsiflexion five times. Force and ankle angle were recorded continuously. The average force from the five cycles at each knee flexion angle was computed for 10° plantarflexion, neutral, 10° dorsiflexion and peak dorsiflexion (approximately 20°).

In Vivo Testing: Passive torque at the ankle was measured bilaterally using an isokinetic dynamometer in 17 subjects (age 33±5 yr): 12 healthy subjects (6 male, 6 female) and five patients with Achilles tendon repair (4 men, 1 woman). Patients were tested within six weeks of surgery and had at least 10° of passive dorsiflexion. Subjects were seated with the knee either in full extension or flexed to 50°. The head of the dynamometer aligned with the lateral malleolus. The dynamometer moved the ankle from full plantarflexion to full dorsiflexion at 5°/s. Two full cycles of motion were performed at each knee flexion angle. Joint torque and ROM were recorded continuously. To ensure that the subjects were fully relaxed, muscle activity was monitored during each trial with surface electrodes placed over the soleus, medial and lateral gastrocnemius and the anterior tibialis. Plantarflexion torque (resistance to dorsiflexion motion) was recorded at 10° plantarflexion, neutral, 10° dorsiflexion and 20° dorsiflexion at both knee flexion angles. Torque values were divided by the estimated moment arm at the ankle to provide an estimate of Achilles tendon force. Moment arm was estimated by averaging the perpendicular distances from the Achilles tendon to the medial and lateral malleoli.

Statistics: The effect of knee flexion angle on Achilles tendon force was examined using repeated measures analysis of variance (knee angle by ankle angle).

Results:
Cadaveric Testing: There was a significant effect of knee flexion angle on Achilles tendon force at 10° dorsiflexion (P=0.037) and at peak dorsiflexion (P<0.001) (Fig. 1). Knee flexion to 45° reduced the Achilles force by 70% at 10° of dorsiflexion and 40% at peak dorsiflexion. Further knee flexion to 90° did not decrease Achilles force at 10° dorsiflexion but at peak dorsiflexion Achilles force was reduced to 60% of the force with knee in full extension.

In Vivo Testing: In healthy subjects knee flexion significantly reduced Achilles forces at neutral (75%, P=0.001), 10° dorsiflexion (54%, P=0.001) and 20° dorsiflexion (46%, P=0.001) (Fig. 2). For the patient group an effect of knee flexion angle was apparent on the noninvolved side but not on the involved side (Side by Knee Angle by Ankle Angle P<0.001) (Fig. 3).

Discussion:
Cadaveric and in vivo testing (healthy subjects) indicated that flexing the knee to 45-50° markedly reduced Achilles tendon forces during passive ankle dorsiflexion. Greater knee flexion did not appear to further reduce Achilles forces. The effect of knee flexion on Achilles forces was not apparent in the ankles with Achilles repairs.

EFFECT OF KNEE FLEXION ANGLE ON ACHILLES TENDON FORCE DURING PASSIVE DORSIFLEXION
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